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TRACK ELEVATION IN CHICAGO, in addition to that mentioned in our issue of Oct. 31, is provided for in an ordinance recommended by the council committee on track elevation. This latest piece of work involves a length of two miles, with 30 miles of track and 34 subways, and will cost about $800,000. The Pennsylvania Lines (P. C. C. & St. L. Ry.) will have 9.12 miles of track and 6 subways; Chicago Terminal Transfer Ry., 5.54 miles, 1 subway; Michigan Central R. R. (terminal line), 4.07 miles, 3 subways; Chicago Junction Ry., 4.20 miles, 1 subway; Grand Trunk Ry., 7.11 miles, 23 subways. The two first roads will raise their tracks between 39th St. and Garfield Boulevard. In 49th St., the tracks from Wallace St. to Western Ave. are to be raised. The street is to be paved for the two miles, in return for which the companies get 13 ft. of sidewalk space on the north side of the street, lying south of their tracks. They are also to build a 6-ft. cement walk on the south side of the street and to put in subways. Another ordinance is to be prepared to compel the Chicago, Burlington & Quincy R. R. to elevate its tracks and to open Robey St.

THE MOSCOW-KAZAN RAILWAY connection, 1,067 miles long, will be commenced this year, and the estimated cost is $63,600,000. There will be three heavy bridges to be built, costing together nearly $7,000,000. These will cross the rivers Selley-Dol, Kama and Byelaya. The Chief Engineer of the new line is M. Budanoff, Engineer of the Ministry of Ways of Communication. This projected line will connect with the Moscow-Kazan line, about 67 miles from Kazan, and shorten the distance between St. Petersburg and Viatka by 267 miles.

THE LAST RAIL OF THE MANCHURIAN DIVISION of the Trans-Siberian Railway was laid on Nov. 3, says a dispatch from St. Petersburg to the "London Mail." This opens the railway from Moscow to Vladivostok.

A DEEP-WATER TERMINAL AT PORT HURON, Mich., is projected by the Botsford-Jenks Co. and the Grand Trunk Ry. Co. Included in the plan is a steel shipyard at St. Clair, to build boats to carry grain from Duluth and Port Arthur to the 1,000,000-bushel grain elevator, now being built by the Botsford-Jenks Co. at Point Edward. This grain would then be shipped by rail to Portland, Me., and carried on the company's ships to Leith, Scotland.

A TEN-HOUR DAY FOR ENGINEERS AND FIREMEN went into effect on Nov. 1 on the New York Central system. This suppliants payment by the run, and will practically mean an increase in wages to the engineers and firemen of slow freight trains who often consume more than ten hours on their runs. And to the men on other trains it means pay from the time the order is issued to report for duty, regardless of waits for the engine.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a butting collision on a branch of the Pittsburg, Fort Wayne & Chicago Ry. near Donelson, Ind., on No. 1. A way freight collided with a construction train returning from work, the caboose, filled with workmen, being at the head of the train. Six men were killed and more than twenty injured.—An accident in which at least three were killed and nearly a dozen badly hurt occurred on the Wheeling Division of the Baltimore & Ohio R. R., near Washington, Pa., on Oct. 30. A westbound passenger train collided just east of Brady's tunnel with a freight engine that had become stalled there by an unimportant collison with another engine only half an hour before. Failure of a flagman to properly perform his duty by warning the oncoming passenger of the obstruction is given as the direct cause of the fatal second wreck.—A similar case of one wreck caused by another occurred on the New York Central Ry., near Grimesville, N. Y., on Oct. 30. An accident on a west-bound freight threw some of its cars over on to the next track. A limited express approaching on that track could not stop in time and was badly wrecked in consequence; fortunately, no one was killed and only two persons were injured.

ON THE OLD EAST RIVER BRIDGE the hangers, some of which failed last summer, are being replaced by hangers of larger dimensions and better steel. The trunnion-nuts are also being replaced by others of improved design. This work was planned by Chief Engineer C. C. Martin immediately after the failure of some of these hangers last summer. The new rods were made by the Bethlehem Steel Works and the new nuts by an Albany firm. These are all now delivered and the first were put in place last week.

CONCRETE-STEEL CONSTRUCTION is to be regulated in France by a commission just appointed by the government for that purpose. This commission will study the conditions to be observed in designing acceptably in that material with the object generally of furnishing engineers and builders with a safe guide in such work; more directly, the work of this commission is expected to relieve the various governmental departments of building and inspection from much undue responsibility in regard to concrete-steel construction now resting upon them.

ALL BIDS FOR THE SEWERAGE AND PAVING OF Havana, Cuba, were rejected by the Ayuntamiento, at its meeting of Oct. 30. Lieut. W. J. Barden, U. S. A., Chief Engineer of the city of Havana, recommended the award of the contract for sewerage and paving to the lowest bidder—McGivney & Rokeby, of Jersey City, the price asked being $10,393,015. Lieutenant Barden informs us that, after adding to his estimate 25% for contingencies and contractor's profits, the lowest bid is only 1.3% above the estimates, the highest bid 9.2%, and the average of the four bids 6.6%.

STEPS TOWARDS WATER PURIFICATION WORKS for Washington, D. C., up to July 1, 1901, included the purchase of 1,377,619 sq. ft. of land at 45 cts. per ft., or a total of $619,929; the beginning of a topographical survey of the site and the preparation of detail drawings; and some excavation. The annual report of Colonel Gillespie, Chief of Engineers, U. S. A., includes an estimate of $1,000,000 for work during 1902-3 on the slow sand filtration plant authorized by Congress.

A WATER POLLUTION SUIT has been brought by the State Board of Health of New Jersey against the Diamond Paper Mills, of Milburn, to restrain the latter from discharging wastes into a millpond which empties into the Rahway River above the point from which the city of Rahway takes its water supply.

MUNICIPAL OWNERSHIP OF WATER-WORKS AT San Francisco is the aim of the city authorities. After some two years of investigation by the board of public works and Mr. C. E. Grunsky, M. Am. Soc. C. E., City Engineer, a report has been submitted which recommends, as an alternative to the purchase of the private plant now supplying the city, new works drawing water from the Tuolumne River. The city has already filed claims with the U. S. Land Office for the necessary water rights and reservoir site. Mayor Phelan states that the city, in accordance with its new charter, will now ask the Spring Valley Water Co. to put a price on its works, so the voters may choose between the existing and a new supply.

BIDS FOR 6,000 WATER METERS are wanted at Cleveland, O., on Nov. 20. The prices must be for meters f. o. b. cars at Cleveland. The sizes are as follows: 5,000 of ⅝-in., with the privilege of 10,000; 800 ¾-in., 200 1-in. and 4 6-in. Mr. Chas. P. Salen is Director of Public Works.

MORE CO-OPERATION BY THE MUNICIPAL DEpartments of St. Louis, Mo., is one of the aims of Mayor Wells now that certain charter amendments have been voted which will enable the city to carry out many street improvements. According to the St. Louis "Republic," the Mayor has said:

> By construction of (electrical.—Ed.) conduits, building of sewers and laying of water mains when the streets are torn up for construction or reconstruction, we would save the expense of additional digging and dispense with the necessity for tearing up streets again after the superstructure had been laid. I am tired of this continual tearing up of streets.

It is understood that work will be pushed rapidly in order to get as much as possible done before the St. Louis Exposition of 1903.

U. S. HARBOR AND COAST DEFENSE WORK is reported upon by General Gillespie, Chief of Engineers, in his annual report. Provision has already been made for emplacing 325 heavy guns, 327 rapid-fire guns and 376 mortars in our harbor defenses, and 25 of the principal harbors of the United States now have a sufficient number of heavy guns and mortars mounted to permit effective defense against naval attack. The principal items in the estimates submitted for new work are as follows: For sites for new forts and mortar batteries and their equipment, $4,000,000; submarine mines and storage facilities, $100,000; searchlight equipment, $500,000; mains and conduits, $500,000; General Gillespie's report upon river and harbor work is very detailed, and the chief items are—under continued contracts, $6,489,377; general rivers and harbors, $12,543,600; surveys and contingencies, $300,000; Mississippi River Commission, $3,695,000; Missouri River Commission, $1,065,200; California Debris Commission, $15,000.

THE NAVAL CONSTRUCTION BOARD recommends the construction of forty more warships, as follows: Three seagoing battleships of about 16,000 tons displacement; two armored cruisers of about 14,500 tons displacement; six gunboats of about 1,200 tons; six gunboats of about 600 tons; six gunboats of about 200 tons; two colliers of about 15,000 tons; one repair ship of 7,500 tons; six training ships of about 2,000 tons; four picket boats of about 650 tons, and four tugboats. These are in addition to the two battleships and two armored cruisers authorized by the last Congress and for which plans have been prepared. The recommendation is in line with the program submitted to the last Congress by Secretary Long as outlining the general policy of the government for providing a modern navy made up of harmonious units and of sufficient strength.

A SEVEN-MASTED SCHOONER, with a steel hull, is being built at the Fore River shipyards. A correspondent of the New York "Tribune" says she will be 403 ft. long over all, will have a beam of 50 ft., a depth of hold of 30 ft., and will draw 27 ft. loaded. She will carry between 7,000 and 8,000 tons of cargo, and spread 43,000 sq. ft. of canvas. She represents a new idea in freight-carriers, substituting wind-power for high-priced coal; and requiring a crew of only 16 men to work her, instead of at least 35 men in a square-rigged ship of the same size. Two six-masted wooden schooners are now in service—the "George W. Wells," built at Camden, Me., and the "Eleanor A. Percy," built at Bath, Me., both in 1900. Experience with these proved that the limit had been reached with wooden hulls, and hence the substitution of steel in this last schooner. The designer of this ship is Mr. B. B. Crowninshield, the designer of the "Independence" and other noted sailing craft. She is being built by a syndicate headed by Capt. J. G. Crowley, of Boston.

THE PHILIPPINES TRANSPORTATION AND CONstruction Co. has bought the four steel steam canal boats and 15 consorts which were built some three years ago to ply between Cleveland and New York on the Lake and the Erie Canal. These boats will be taken to pieces, shipped to Hongkong and after being reassembled, they will proceed to Manila to do general lighterage and interisland business. The reason given by the Cleveland Steam Canal Boat Co. for withdrawing these vessels from the canal trade is that grain rates are so low that there is no profit in eastbound tonnage. It is claimed that the consolidation of railways has enabled these companies to obtain rates that enable them to successfully compete with the canals. The want of railway facilities in New York for the canals is another element.

A CANAL CONNECTING the Black and Caspian Seas is proposed in connection with the improvements of the Sea of Azov, recently reported in these columns. The canal would extend from Taganrog on the Sea of Azov to Astrakhan on the Caspian, by way of the Volga. The proposed dimensions are: Width, 84 ft.; depth, 22 ft.; the projected route calls for 530 miles of canal. The water would be drawn from the mountain streams Terek and Kuban. The excess of water could be utilized for irrigation and for generating electric power.

A DAM ACROSS THE CHARLES RIVER, between Boston and Cambridge, is to be reported on by a commission of three members, in accordance with an act of the last legislature. The Governor has just appointed the following commissioners: Messrs. Henry S. Pritchett, President Massachusetts Institute of Technology, Boston; Col. Samuel S. Mansfield, U. S. Engineer Corps, New York; Richard H. Dana, Cambridge. The object of the proposed dam is to form a water park.

A ROYAL TRAIN IN CANADA.

One of the most elaborate special trains ever operated was put in service recently by the Canadian Pacific Ry. for the transcontinental trip of the Duke and Duchess of Cornwall and York. The Canadian trip covered over 7,000 miles, the route being from Quebec to Montreal, Ottawa, Winnipeg and Vancouver, returning by the same route and proceeding from Montreal to Halifax by the Intercolonial Ry.

The special train was made up of nine cars, three of which were built specially for this train at the Montreal shops of the Canadian Pacific Ry. The train, exclusive of engine and tender, was 730 ft. long and weighed about 595 tons. The cars were all mounted on six-wheel trucks and provided with wide vestibules. They were lighted by electricity and fitted throughout with a complete telephone system. The exterior finish was of natural mahogany, in the standard style of the two railways above noted, while the interior finish, decoration, upholstering and furnishing were all of a most elaborate character. Except on the mountain divisions the train was hauled by one of the new four-cylinder compound engines of the Atlantic type.

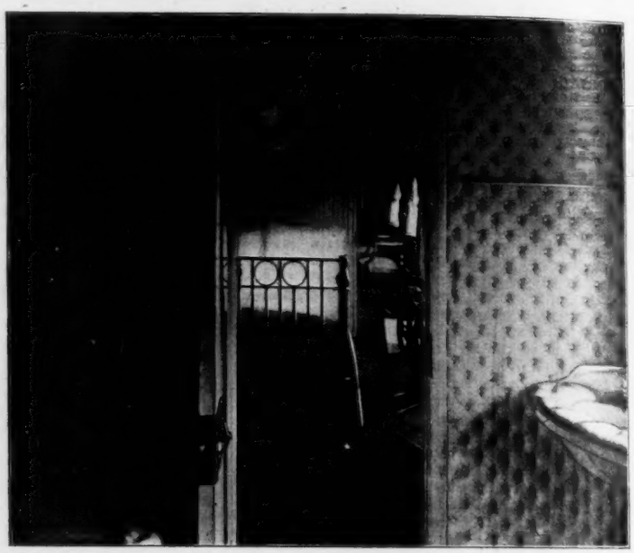
The rear car of the train was the "Cornwall," intended for use by day, having a large reception room at the rear opening onto an observation platform protected by sides, a hood and an ornamental railing. A notable piece of furniture in this room was an upright piano. This car was 78 ft. 6 ins. long and 10 ft. 3 ins. wide, weighing nearly 60 tons. At the middle of this car was the royal dining room, seating eight persons, and separated from the reception room by a boudoir at one side, and the kitchen and refrigerators on the other side. The boudoir and kitchen were each passed by a corridor. Next to this was the sleeping car "York," with two bedrooms and bath rooms at the center, and attendants' rooms at either end. The bath rooms were draped in waterproof cloth.

The third car from the rear was the compartment car "Canada," for the use of the staff. This had state rooms, bath room, shower bath and a large smoking room fitted with desk, lounges and easy chairs.

Next to this was the dining car "Sandringham," 70 ft. long in the body, 77 ft. 3 ins. long over the platforms, and weighing 57 tons. This was for the use of the staff of the royal party. The dining room was arranged in the usual way, with tables on either side, accommodating 30 persons at a time. This car was finished in red mahogany, with a ceiling of dull gold, and hangings and carpets of green, the chairs also being upholstered in green leather. Ahead of the dining car were three standard sleeping cars of the Canadian Pacific Ry.: the "Australia," "India" and "South Africa," the latter altered to provide a room for the medical attendant. At the head of the train were two baggage cars; one of these contained baggage and had accommodation for the trainmen, while the other was fitted up as a cold storage car for the commissariat service.

A special train was run ahead of the royal train, and to this were attached two private cars of the Intercolonial Ry., specially built by the Barney & Smith Car Co., of Dayton, O.

View in the Dining Room.



View of Bedroom and Bathroom.

THE ROYAL TRAIN USED BY THE DUKE AND DUCHESS OF CORNWALL AND YORK IN THEIR CANADIAN TOUR.

A PIECE OF DIFFICULT SHAFT SINKING IN DEVELOPING THE SALT MINES OF GRAND COTE ISLAND, LOUISIANA.

By J. N. Hazlehurst,* M. Am. Soc. C. E.

In a section of country extending from the Atchafalaya River to a point midway between the towns of New Iberia and Abbeville, on the Louisiana Gulf coast, lie, in the order named, Belle Isle, Cote Blanche, Grand Cote, Petit Anse and Cote Caroline; each "island" rising in rolling hills from out the sea marsh and prairie; all similar as to their general characteristics, but differing radically as to topographical and geological formation from the nearby mainland, which is uniformly flat, alluvial land for several hundred miles west of the Mississippi River.

Upon four of the five so-called islands, extensive deposits of a wonderfully pure rock salt have been discovered, three of which are being developed at this time. In the initial work of opening the mines on Grand Cote or Week's Island by the Myles Salt Company, Ltd., of New Orleans, the writer was retained as consulting engineer, prior to which engagement he had made a report upon the property for a financial institution, fragments of which report follow in order that a clearer conception of the work attempted and performed may be had:

GEOGRAPHICAL.—Grand Cote, or Week's Island is one of a chain of coast islands along the Gulf of Mexico, in the parish of Iberia, state of Louisiana, 120 miles west of New Orleans. The island is a tract comprising some 2,000 acres of arable land, rising 180 ft. above the sea level and partly surrounded by Vermilion Bay, but separated from the mainland by a thick cypress swamp some three-quarters of a mile in width, over which a corduroy causeway has been constructed. The general character of the land is rolling; rising in abrupt knolls or hills from the swamp toward the bay where bluffs 180 ft. above tide water break and slope to the sea. The soil is fertile and the area is cultivated, sugar cane being successfully planted and the sugar manufactured at a sugar-house located upon the island. From a geological survey of the state the following is quoted:

By far the most unique and probably the most important mineral product of Louisiana is the deposit of rock salt known to exist upon Petit Anse and [illegible] islands, and in all probability upon Grand Cote, [illegible]che and Belle Isle as well; as also beneath the [illegible]mediate marshes. These salt deposits, supposed to [illegible]taceous in age, are at the southern extremity of the so-called "Cretaceous backbone" of the state. For [illegible] line salt springs have been known to issue along [illegible] as the names "Saline Bayou" and "Saline Lake" [illegible] and the old abandoned salt-works in the northern [illegible] state, show that at an early date in the history [illegible]siana salt, manufactured from these springs and [illegible] became a commercial product. It was only du[illegible] Civil War that deposits on Petit Anse were d[illegible]d; and in 1894 or 1895, that a like discovery w[illegible] upon Orange Island. Salt was also found upon [illegible]sle and Grand Cote in 1896.

At Petit Anse salt has been for years ext[illegible] mined and a cave in one section of the mine [illegible] the salt lying within 15 ft. of the surface and direct[illegible]laid by Lafayette gravel. In another part of th[illegible]nd the salt deposit has been penetrated to a dep[illegible],000 ft. without reaching bottom, and Orange Islan[illegible]ent re-ports from Capt. A. F. Lucas) shows a c[illegible]lis bed of rock salt penetrating for 1,800 ft. wi[illegible] passing through it. Such thickness of rock salt is k[illegible]nowhere else in the United States, and in but few p[illegible] in the whole world.

It is generally assumed this thickness is t[illegible]sult of evaporation of a land-locked sea, its continuit[illegible] purity proclaim a constancy of conditions that sub[illegible]ent and frequent oscillations of the region discredit. [illegible]ases of the rock salt from Petit Anse show it to be [illegible] 99%

*Chief Engineer, Department of Engineering, city of Mobile, Ala., and Consulting Engineer for the Myles Salt Co., Ltd.

pure, and it is difficult to imagine a constant supply of sea water during the accumulation of more than 1,000 ft. of salt without any admixture of mechanical sediments or other impurities, etc.

HISTORICAL.—Petit Anse, the first of the islands upon which salt was discovered, is owned by the Avery Estate, and has been mined more or less successfully for 30 or 40 years, the salt being first evaporated from wells whose water overlay the salt beds. During the period of the Civil War these mines supplied a large portion of the salt used by the Southern Confederacy, and on account of the increased demand, an attempt was made to deepen the wells, resulting in the discovery of rock salt some 40 ft. below the surface. Later a shaft was sunk, works erected and for the past 15 years the mines have been extensively operated.

Owing to improper methods of mining in which the galleries and counter shaft were extended within a few feet of the overlying and water-bearing sand, the mines were flooded and a new shaft was completed at another part of the island. At the time of the flooding of the old mines, the Myles Salt Co., Ltd., were operating under a royalty lease, and as litigation arose in connection with this misfortune, the mines reverted to the owners, and the Myles Salt Co. began to prospect for other salt fields. Their first efforts were directed to Cote Caroline, or Orange Island, then the property of the veteran actor, Mr. Joseph Jefferson, upon whose place salt was discovered, but at so great a depth below the surface and with such a quantity of quicksand overlying that it was not thought feasible to open a shaft. Abandoning their efforts at Orange Island, in 1898, the Myles Salt Co. prospected Grand Cote or Week's Island, driving 28 test holes with a diamond drill, over an area of two miles in length and one in width, and carrying their drill to a point between 500 and 600 ft. below the first evidence of salt without reaching its lowest limits. Cores from these test holes show specimens of most beautiful salt crystals of remarkable purity on analysis.

PROPOSED DEVELOPMENT.—The general scheme for the development of this property is the sinking of a shaft

to a depth of 500 ft., of which the first 90 ft. penetrates the island soil of loam, clay and water-bearing sand and gravel, reaching salt at the former depth where an impervious joint between the caisson and the salt will be effected, and the shaft will be continued 410 ft. further in salt, 100 ft. of which will be cased as a further protection. At 500 ft. below the ground surface lateral galleries will radiate from the shaft, and be opened some 50 to 80 ft. in width and the same in height, with supporting columns at intervals.

It is proposed to mine the salt by compressed-air drills, undercutting and blasting from the face, and handling the product with approved machinery. Directly over the shaft will be erected the "headhouse" of timber framework 105 ft. in height, with pulley, operating a cable of 1¼-in. steel, passing over a 12-ft. diameter conical drum in engine house, controlled by two 22-in. × 36-in. en-

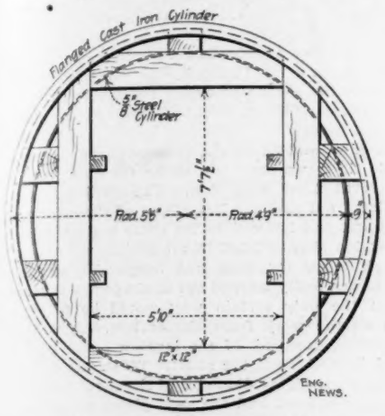


Fig. 1. Sinking a Shaft at Grand Cote Island, Louisiana. Plan of Cast-Iron Cylinder; 5/8-in. Steel Cylinder, and Timbers in Place.

gines, supplied by two boilers of 150 rated HP. capacity. Attached to the other end of the hoist will be a double-deck shaft cage. When mined, the salt will be elevated 105 ft. to the "tipplehouse," where the carriage will be dumped, the salt crushed and screened, passing in assorted sizes into covered and convenient bins, located on either side of a railway track, provided with track scales. Under an arrangement with the Southern Pacific Railway, its branch line from Franklin to Cypremort will be extended to the mines and it is also proposed to construct a tram line from the mill building to Garret's bayou, 2,400 ft. distant, where light draft schooners may effect a landing. The mill building will occupy a space of some 125 by 110 ft. It will be of lumber, mill construction, approximately 500,000 ft. B. M., and the capacity of the works will approximate 400 to 600 tons of merchantable salt per day.

ACTUAL DEVELOPMENT.—The work of development and construction accomplished to date (March 21, 1900) has been the preliminary experiments and tests with the diamond drill, resulting in the location and driving of a shaft to a depth of 105 ft.; casing same with cast-iron segments of a cylinder 11 ft. 4 ins. in diameter, 18 ins. in height, and consisting of nine segments and key. The segments have vertical and horizontal flanges 1 in. thick, cast with the segment, which is 1½ ins. in thickness. While well cast, the flanges are not machined, the irregularity at points of contact being taken up with tarred paper, and the connections made with ¾-in. bolts. Below the water line there is considerable leakage along the joints so made.

Owing to the presence of quicksand and inadequate equipment, the work of sinking and casing the shaft has been necessarily slow and expensive; but the work, under Mr. Geo. Cowie, former engineer of the Royal Salt Mines of Kansas, has been well done and substantial and the shaft is fairly perpendicular. The water bearing sand or "quicksand" was encountered 42 ft. below the surface, but has been controlled by a small simplex pump. In proceeding further, the immediate difficulty will be in controlling the flow of subterranean water with its tendency to choke the shaft with sand, and of sealing the joint where the salt comes in contact with the caisson now in place. . . .

After the visit and report in March, very little was attempted until the writer was retained as consulting engineer to the company in June of the same year, when a careful consideration of the methods employed and of those proposed was given. It seemed useless to attempt to proceed further by pumping out the shaft as it had been repeatedly shown that so soon as the head of water, as determined by the line of saturation of the sand, was reduced to a certain point, the sand started to run into the shaft, flowing in under the cutting shoe, dissolving the salt, and permitting the whole caisson to settle, and resulting in a deposit of from 10 to 15 ft. of sand inside the caisson.

A previous attempt had also been made to telescope the joint or point of contact between the caisson and the salt through the use of a 5/8-in. steel cylinder, in 5-ft. rings, 15 ft. in all having been riveted together and lowered from the top. This cylinder was 9 ft. 6 ins. in diameter, and had never been removed from the shaft. With this interior cylinder in place, it had been thought possible by a former management to prevent or partially obstruct the further inrush of water and sand by sinking in the annular space between the caisson and this cylinder a number of 3-in. diameter pipes into which a carload or more of cement grout was pumped. It was thought that the grout would form a cement mortar when mixed in this way with the sand, and that it might set, reducing in part or entirely the space about the foot of the caisson. Afterward, when the steel cylinder was removed, a considerable quantity of this cement mortar was found between the inner cylinder and the circumscribing caisson, partly closing the annular space.

Numerous suggestions had been made and considered; probably the most feasible being that from Gen. Wm. Sooy Smith, for making this joint by the application of the process patented by him and generally known as the "freezing" process, which consisted in driving pipes through the quicksand, attaching to a refrigerating machine, and freezing the water and sand in a circle about the shaft or tunnel that was to be cased or lined.

After a careful investigation of the subject, the most promising method of handling the work seemed to be through the application, in some form, of compressed air, and accordingly an advertisement was published requesting proposals from contractors equipped for pneumatic work, upon specifications which permitted the contractor to execute the work in such manner as seemed to him most likely to succeed, subject to the approval of the engineer. The contractor was to remove all obstructions, to complete the work within a specified time, and to provide a solvent bond for execution, and maintenance for twelve months after acceptance. In addition to effecting an impervious joint between the salt and caisson, the contractor was required to extend the shaft by excavating the salt a further depth of 90 ft. below the shoe of the caisson.

After considerable correspondence, a contract was effected with Mr. Chas. A. Haskins, No. 16 City Square, Boston, Mass., an experienced contractor for subaqueous work by pneumatic process. In November, 1900, an outfit was installed, consisting of a 10 × 16-in. compressor, with 42 × 72-in. receiver, with sufficient 3-in. discharge pipe; a single air-lock, with steel connections and a small electric light plant. The company provided two 150-HP. boilers, already in place, a suitable hoist, and miscellaneous tools.

At the time of commencing operations, the obstructions to be removed consisted of the steel inside cylinder previously mentioned, about 12 ft. of sand and rubbish in the bottom of the shaft, and sets of 12 × 12-in. timbers, which had been framed on each of the horizontal flanges of the caisson for the purpose of squaring-up the shaft and giving it additional strength. The first work was the spiking together of timbers to form a deck at the water-line, and upon which the steel connections to the lock could be supported. This arrangement, with the lock in position, and inlet air pipe, is shown in Fig. 2.

As the air was supplied, the water was driven back, but owing to the fact that the flanged connections of the caisson, although including a gasket of tarred paper, leaked badly, much air was lost, and in order to reach the leaks, every other set of the 12-in. timbers was gradually removed, and the flanged joints, wherever accessible, were plastered with cement grout. So badly did these joints leak, that two workmen were detailed constantly to find the leaks, using the flame of tallow candles for this purpose, and when found, to plaster or wash the places with liquid cement grout.

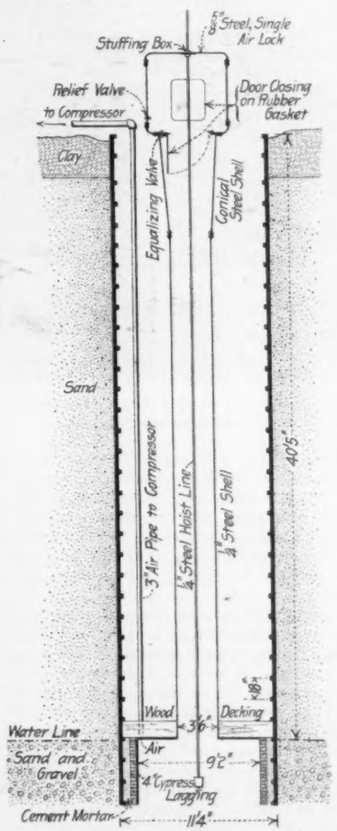


Fig. 2. Section of Shaft Above the Deck; Showing Air-Lock in Position.

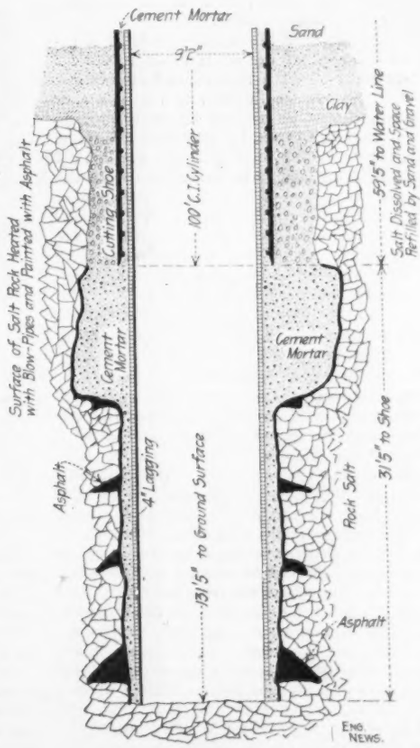


Fig. 3. Section of Shaft Below Shoe; Showing Method of Making the Joint.

The work of removing the timbers was necessarily slow and expensive, as the longer pieces would not pass through the lock until cut in two. Finally, the water was forced down until the sand in the bottom was reached, and this was hoisted to the surface in canvas bags, exposing the salt, which was found to be very irregular in surface, at one side being worn or dissolved so as to leave a space of about 4 ft. under the shoe. This cavity made some 2 lbs. more pressure of air necessary than was anticipated.

Only a portion of the shoe of the caisson rested upon the salt, and the castings composing the caisson above the shoe, which was of steel, were broken and cracked in several places, making a weak spot at that important point. Throughout, some 25 to 27 lbs. of air, as shown by gage, was required to sustain the column of water above, and with this pressure it was necessary to reduce the working hours to 8 for each of three shifts during the 24; but notwithstanding short hours, the workmen complained considerably of "caisson disease."

As soon as the shaft was made reasonably tight, poling boards were driven at right angles to the shoe and back to the salt, and thoroughly plastered with puddle clay. The salt was excavated to a depth of about 5 ft. below the shoe, and a shoulder cut upon which to construct a temporary joint of cement mortar, which made a closure at the shoe. The steel cylinder, which had remained undisturbed, was then hoisted up and suspended about 10 ft. above the shoe, the alternate sets of timber that had been left in place being cut out and removed to make way for this operation.

All being clear, the salt was carefully picked out for several feet further to prevent disturbance, after which light charges of dynamite were used, and the shaft carried down 30 ft. below the shoe. During this time, the caisson was being sustained partly by the air pressure upon the deck and partly by the frictional resistance of the sand along its outer circumference.

The general plan of the work permitted a reduction of the area of the shaft to about 9 ft. 2 ins., which gave about a foot space between the caisson and the interior lining, and this space, it was decided, should be utilized by using cypress lagging or curbing, 3 ins. in thickness by 4 ins. in width, cut to radius of 9 ft. 2 ins., and spiked face to face. This was to be carried up from the shoe to the water line in order that the caisson might be made water-tight throughout. The same construction was to be used below the shoe for the 30 ft. excavated; except that the cement was to fill the space between the lagging and salt, which it was intended to carry back about a foot from the face of the lagging. In addition to the cement mortar, it was decided to place at intervals, rings of asphaltic cement, to act as insulators, or to prevent the penetration of moisture.

Prior to deciding upon this line of action, experiments were made both by the contractor and the writer, to determine the effect of the cement mortar and asphaltic cement when in contact with salt. It was found that moisture in the hydraulic cement mortar "took up" or dissolved a certain amount of salt, leaving an imperceptible space between the mortar and salt, but sufficient to cause danger, as this space would rapidly increase as the salt was dissolved in contact with flowing water. It was found that by using a brine at the full point of saturation, instead of fresh water in mixing the mortar, a better contact was possible; and, therefore, strong brine was used throughout, the cement setting up as would be expected under normal conditions. Trials of asphaltic cement demonstrated the fact that the moisture in the salt prevented a close adhesion; and notwithstanding that the asphalt was applied while hot, as soon as cooled, it could be stripped from the salt like molasses candy from a buttered plate. Heating the salt was next tried, and by this process, and with the salt at a dull red, the asphalt acted perfectly and a close contact was secured.

These preliminaries having been satisfactorily settled, the salt was cut back at the bottom of the shaft to a shoulder; the first course of the lagging laid; and after heating the salt with blowlamps, asphalt was run into the space so formed and the lagging carried up a convenient height. Cement mortar, mixed one part cement to one of sand was used "dry" and packed into the annular space between the salt and lagging, and so the lining was carried nearly up to the shoe, covering the short or temporary joint previously made. From the latter point it was deemed a simple matter to rapidly carry the lagging up to the water line, backing with mortar, as previously explained.

At this juncture the first bit of misfortune came in the shape of a fire in the shaft, the upper set of timbers, which had become very dry, igniting from the candle flame, and this, fanned by the air pressure and additional oxygen, soon made the shaft a very furnace, driving the men to the outside. Finding that the fire was rapidly gaining headway with the lower sets of timbers, operations were suspended, the water rushed in from below, and the shaft settled about 18 ins. The flames were finally extinguished by sealing the door of the lock, and after three days operations were once more resumed.

Sand to a depth of some 12 ft. had come into the shaft, and this was hoisted out as before, when an inspection disclosed the fact that the shoe and some more of the lower plates of the caisson were broken out, and that the short joint had been made shorter by about 3 ft.; while the shaft had settled somewhat out of plumb, which could not but have warped the work below. "A council of

Fig. 4. Salt Mines at Grand Cote Island, La. The First Salt Excavated by the Myles Salt Co., Ltd.

war" was held, and it was determined that the lagging should be stripped away to a point about 7 ft. below the shoe, and upon the shoulder thus formed, the steel cylinder which had remained suspended, should be lowered, telescoping the joint with its broken plates, and leaving a space of about 3 ins. at all points, which it was decided to grout.

This plan was carried out, and it gave promise of adding much to the strength of the shaft at its weakest point; but unfortunately, after the completion of the work and a lessening of the air pressure, several leaks appeared around the lower part of the steel cylinder, admitting water to such an extent that the cylinder was ordered removed.

It had been expected that after the joint was made and the deck removed, the cylinder could be hoisted out of the shaft; but its presence under the new condition of things became embarrassing. It could not be hoisted out through the lock, and it was, therefore, necessary to dispose of it in some other way, since it had also failed in its mission of reinforcing the broken caisson plates at the joint. Two lines of horizontal and most of the vertical rivet heads had been "snapped" off, and the plates of two rings of 5 ft. each had been lowered temporarily to the bottom of the shaft, when it was reported that the caisson up about the deck had cracked for about 20 ft. vertically. Whether the fire about that point had caused an expansion of the cast-iron segments to such an extent as to cause rupture, or whether th[illegible]as the result of air waves vibrating to the b[illegible] of the workmen cutting out the rivet heads i[illegible] known. The fact remained, however, that the [illegible]k first showed for about 20 ft. along the verti[illegible]anges, and that this crack, which at first me[illegible]d only ⅞-in., widened to 2¾ ins., so that it [illegible] almost impossible to hold the pressure sufficien[illegible] to keep back the rising water at that distance [illegible]w the deck, and it looked as though the shaf[illegible]s lost.

Fortunately, there was sufficient la[illegible]g on hand to reach from the shoe to the w[illegible] level, and this was put in position as rapidly possible, being backed with cement mortar [illegible]ach 2 ft. vertical was laid, and the pressure [illegible]s thus maintained until the lagging covered [illegible] crack from top to bottom. As the pressure was [illegible]st by the rupture of the plates of the caisson, permitting the water to rise in the shaft, a further slight settlement of the caisson was observed, and, as before, the shaft was partly filled with sand.

As soon as the caisson had been secured and the leaks prevented, work was again commenced at the shoe, and as before, poling boards were used; this time two sets, one above the other, and the interval filled with clay. The sand was again hoisted out and the last plates of the steel cylinder cut and lowered to the shaft bottom. An inspection showed that in all probability the joint work below the shoe was irreparably damaged, as it was badly warped out of shape and it seemed that the only certain way would be to recommence the work from the bottom. Accordingly this was done; all of the lagging being torn out and hoisted from the shaft. When the salt was fully exposed, the diameter of the shaft was somewhat increased, and the steel plates remaining at the bottom were set upright along the sides of the salt and grouted in as the lagging and filling was brought from the bottom upward. Several deep recesses or shoulders were cut in the salt and into those asphaltic cement was poured, this portion of the work being shown in Fig. 3.

All exposed surfaces of the salt were carefully heated to a cherry red and "painted" with asphalt and the work was carried as indicated from the bottom of the shaft to a point about 6 ft. above the shoe, where a junction was made with the lagging which had previously been placed from the shoe upward. In order to make certain that the space immediately about the outer circumference of the caisson had entirely filled, several holes were bored from the inside of the shaft through the lagging, just below the shoe, and small pipes inserted; through these pipes cement grout was pumped as long as the pressure would force the grout back; the pipes were then withdrawn and the holes plugged. As soon as the connection was perfected, the air was gradually reduced until it equalized with the outer air, when the lock doors were thrown open and the work was comp[illegible]ete as far as the joint was concerned.

At first there was a very perceptible sweat and drip at points throughout the shaft above the shoe, but these "took up" in a few days. Realizing that the work had been fully successful, within a few days the deck and lock were removed and the excavation in open cutting was carried down about 60 ft. further without difficulty; after which the work was inspected and accepted subject to the twelve-month maintenance clause of the contract.

In the execution of this work too much praise cannot be given to the contractor, Mr. Chas. Haskins, for his persistence and resourcefulness, and to his energy and courage are to be attributed largely the success of this undertaking. As stated previously, it was the intention of the company to carry the shaft to a depth of 500 ft. before countermining, and to this date the work is something over 300 ft. below ground. The character of the salt continues most satisfactory. No fault or flaw in the deposit has been encountered, and the shaft throughout is absolutely dry.

THE SHAWINIGAN FALLS WATER & POWER CO., at Quebec, has just completed its canal No. 1, designed to supply water for a total installation of 50,000 HP. The capitalists interested in the work inspected the canal a few days ago. Power at this plant is to be developed by units of 6,000 HP. each.

CONTRACT TESTS OF AUTOMATIC STOKERS AT THE GENERAL ELECTRIC WORKS, SCHENECTADY, N. Y.

Twelve under-feed automatic stokers,* made by the American Stoker Co., of New York city, were recently purchased by the General Electric Co. for use under six Stirling water-tube boilers at its Schenectady works. The contract under which these stokers were installed contained a peculiar guarantee as to efficiency and performance in various particulars, which was drawn up by the Engineer and Manager of the American Stoker Co., Mr. J. MacCormack. To determine whether that guarantee had been fulfilled, it became necessary to make an elaborate test of these stokers, and also of a plant of Roney stokers, installed some time previously. This test was made by a board of engineers consisting of Prof. J. E. Denton, of Stevens Institute, Hoboken, N. J., Mr. F. W. Dean, of the engineering firm of Dean & Main, Boston, Mass., and Mr. Geo. H. Barrus, Boston, Mass.

We have been favored with a copy of the report rendered by these engineers dated July 23, 1901, and quote from it as follows:

We have conducted the guarantee tests and investigations required under the contract between the American Stoker Co. and the General Electric Co. for the installation of 12 stokers under six 517.5-HP. Stirling boilers, and beg to report as follows. The contract for the installation of these stokers contains the following clauses relating to the guarantees and the methods of determining their fulfillment:

1. By the proper use of the stokers, the stack shall be practically smokeless except at such time as fires are being cleaned, new fires started or boilers unduly forced.

2. We will guarantee by the proper and intelligent use of these stokers an evaporation of 11.5 lbs. per lb. of dry coal from and at 212° F., based on the use of the following coals: Cumberland, Clearfield, George's Creek, New River, or their equivalent, containing not less than 14,500 B. T. U.'s, determined by standard calorimeter.

3. We guarantee an increased capacity above builders' rating by the proper use of these stokers and the breaking up and stirring up of fires on either side of stokers with bar through holes provided in furnace doors for that purpose 33⅓% increase.

4. We assume all repairs and renewals that are above five per cent. (5%) over contract price, due to proper use and incident to wear and tear in the operation for the first two years from date of actual operation by your company.

5. The American Stoker Company agrees to generate a net horse power of steam as economically as the Roney stoker.

In determining the guarantees as made, it is agreed that no boiler test shall be run for less than ten (10) hours nor longer than twenty-four (24) hours. During efficiency trials, the boilers are to be run at or within ten per cent. (10%) of their nominal rating, this rating being specified in Article VII. of the accompanying proposal. (Article VII. specifies that the nominal horse power of each boiler is 500 HP.) All guarantees are based on the use of fresh coal during tests. All results are to be based on dry coal. During the stoker test, the firemen are to be subject to the orders of the contractor's representative. Prior to the final test, preliminary tests may be run by either party.

Our interpretation of the exact meaning of the above specifications relating to the guarantees is that, first, the boiler should be capable of evaporating 11.5 lbs. of water from and at 212° per lb. of dry coal without correction for steam used by the stoker apparatus, using one of the coals named, the same to have a calorific value of not less than 14,500 B. T. U., as determined by a standard calorimeter; second, that the boiler should be capable of developing 33⅓% more boiler horse power (not corrected for steam used by the stoker apparatus) than the stoker company's rating of 500 HP.; third, that the stoker should secure a practical absence of smoke except at times of cleaning or working the fires; and fourth, that the Stirling boilers fitted with the American stokers should generate a given amount of steam as economically as the Babcock & Wilcox boilers fitted with the Roney stokers in the same boiler house, taking into account the expenses of operation, embraced in the cost of fuel, labor, interest, depreciation, and repairs of stokers, and cost of steam used in operating the stoker apparatus.

The report then continues with a description of the plant and account of the tests, which we abstract as follows: The Stirling boilers to which the American stokers are attached were put in service early in 1901. Each contains two furnaces 6 ft. long and 6 ft. 11¼ ins. wide. The Babcock & Wilcox boiler tested was put in service in 1898, and the Roney stoker attached was started in February, 1900. The dimensions, etc., of the American stoker is described as follows in the report:

The stoker used is the one designated by the makers "No. 10," the retort of which is 6 ft. long and 13 ins. wide inside at the top of the tuyeres. The tuyeres are provided with removable caps and the air openings are located wholly on the inside; that is, the side next to the retort space. There are no openings on the outside save those due possibly to loose fits of the tuyere caps and tuyeres. The tuyeres have a width, at the top, of 5 ins. The grates, which are at each side of the retort, slope downward for a distance of 15 ins., and the vertical distance at the bottom of the slope below the level of the top is 6 ins. At the bottom of the slope on each side there is a level grate 15 ins. wide, and this is arranged in sections and provided with mechanism for dumping into the ash pit. The tuyere boxes are supplied with air under pressure from the main duct, which is located at the rear of the furnaces beneath the boiler. Air is also supplied from this duct to each ash pit through two pipes, one on each side of the tuyere box. The two ash pits for each boiler are independent. Dampers are provided in the ducts leading both to the tuyere boxes and to the ash pits, so that the pressure of air at either point can be regulated at will. The ash pits can be closed at will by shutting the ash-pit doors. The sloping grates and the dump grates are all provided with air openings. The area of grate surface on each side of each retort is 15 sq. ft., and of this about 21% consists of air openings. The total area of grate surface at the sides of the retort for each boiler is 60 sq. ft.

The blast is furnished by a Sturtevant fan which is supplied with power from an electric motor to which it is belted. One fan supplies the power for three boilers.

The Roney stokers were attached to standard double-deck Babcock & Wilcox boilers of 412 HP. rated capacity.

The tubes of both boilers were, before the test, thoroughly cleaned of all scale on their inner surfaces, and were blown with steam on the fireside.

The tests were all substantially in accordance with the standard code laid down by the American Society of Mechanical Engineers. The alternate method of firing was used as far as this could be done on boilers fitted with mechanical stokers. Coal from the New River mine was used in the final tests, as being satisfactory according to the specifications. Its calorific value was about 14,900, calorimeter determinations and calculations from analysis agreeing closely. The percentage of ash was about 5.0. Preliminary tests were made with Reynoldsville coal from the Soldiers Run mine; but the average of this coal used was found to fall considerably below the guarantee specification of 14,500 h. u., though a test sample had given the value 14,617 h. u. This coal, also, was found to be much more smoky than the general run of Cumberland, Clearfield and New River coals as specified, showing on proximate analysis nearly 10% excess of volatile matter over the amount usually found in these coals.

The handling of the stokers was a matter to which some attention was given. On all the economy tests with the American stoker the blast was supplied through the tuyere box in the center; the ashpit doors were closed and the only air supplied beneath the side grates was the leakage past the dampers in the supply ducts. On the capacity test the dampers on the sides of the ashpits were open one notch, sufficient to give a slight air pressure in the pits. As a result of the experience gained in the preliminary tests, it was found best to run the slice-bar in and out along the edges of the tuyeres about every half-hour to hour, and to rake level the bed of coal on the side grates about every hour. More handling was found to give distinctly inferior results as regards economy and quantity of smoke. On all tests of the American stokers, the general plan of handling the fires consisted in keeping the sides near the brickwork covered with live coal, having a thickness varying from nothing to four inches, and depending for the main part of the work upon the combustion of coal in the center.

The system of operating the (Roney) stokers on the B. & W. boilers consisted in keeping a constant rate of feed, and occasionally dumping the ashes and clinkers from the lower grates. The stokers were frequently assisted by poking the coal down the inclined grate, using a short bar introduced at the corner doors, poking the coal from time to time from the hopper into the passage leading to the furnace, and occasionally moving the clinkers which formed between the grates by running in a thin slice-bar from beneath. The coal that dropped down through the grates of the stokers was shoveled back into the hopper. In one test this amount was weighed and was found to be 8.1% of the total quantity consumed.

It may be added here that representatives of the manufacturers of both stokers and of the Stirling boilers were present at the tests.

No systematic attempt was made to determine the precise degree of smokelessness attained, but frequent observations were made of the gases escaping from the stacks. Whenever the stokers were operating in a normal manner, and the fires were not worked by hand in any way, there was practical absence of smoke, the results in this respect being about the same for the two stokers.

The conclusions formulated by the engineers who conducted the tests follow:

1 ECONOMY OF STIRLING BOILER AND AMERICAN STOKER.

The economy realized by the Stirling boiler and American stoker under the conditions prescribed by the contract, is shown by the test of June 6, 1901. The result of this test is a gross evaporation from and at 212° per lb. of dry coal of 11.889 lbs., and a net evaporation of 11.743 lbs. The guarantee calls for 11.5 lbs. Consequently, the results obtained exceed that guaranteed by .389 lbs. gross and .243 lbs. net per lb. of coal, which are respectively 3.4% and 2.1% above the guarantee.

2. CAPACITY OF STIRLING BOILER AND AMERICAN STOKER.

On the test of June 8, the boiler developed 716 gross horse power and 705 net horse power, which quantities are respectively 38.4% and 36.2% above the builders' rated capacity of 517.5 HP. The stoker contract stipulates a rated horse power of 500. On this basis, the percentages are respectively 43.2% and 41% above the rating. The contract calls for an increase of 33⅓% above the rating; consequently, whichever rating is taken the guarantee is amply fulfilled.

In this connection, it may be stated that the boiler was not crowded to its utmost capacity, there being, as the record shows, practically no blast under the side grates. For a period of one single hour during the trial, the amount of water evaporated was 24,120 lbs., which represents 835 HP. or 60% above the rated capacity of 517.5.

3. COMPARATIVE ECONOMY OF THE AMERICAN STOKER AND RONEY STOKER.

The relative economy of the two stokers is based on the cost of steam produced per rated horse power per year, embracing cost of fuel, repairs, labor of firemen and helpers, interest and depreciation on the cost of the stokers.

FUEL.

The cost of fuel is derived from the results of the tests of June 18 and 19, taking the price of coal at $3 per ton of 2,240 lbs. In the case of the B. & W. boiler and Roney stoker, the net evaporation from and at 212° per lb. of dry coal was 11.169. The weight of coal used per horse power per year of 360 days, 24 hours per day, is $\frac{34.5 \times 24 \times 360}{11.169} = 26{,}698$ lbs. or 11.92 tons. This, at $3 per ton, costs $35.76.

In the case of the Stirling boiler with American stoker, the weight of coal used per year is $\frac{34.5 \times 24 \times 360}{11.421} =$ 26,603 lbs. or 11.65 tons. This, at $3 per ton, costs $34.95.*

REPAIRS.

An examination of the General Electric Company's log books of the boiler room, show the repairs that have been made to the stokers for the periods during which the boilers have been in operation since repair records have been kept, and furnish data for determining the cost of the repairs. For the Roney stokers, those attached to the 412-HP. boilers were the only ones considered. Most of the repairs consisted in the replacement of grates, and it was a simple matter to determine the weight of iron that had been renewed. Reducing the quantities to the equivalent of the number of pounds renewed for one 412-HP. boiler, it was found that 24,277 lbs. of iron was renewed after 31,900 hours of service. This is equivalent to $\frac{24{,}277 \times 8{,}640}{31{,}900 \times 412} = 16$ lbs. per HP. per year. The cost of these castings to the General Electric Company being 3 cts. per lb., this weight of metal represents $16 \times .03 =$ $0.48 per HP. per year.

The repairs to the American stokers consisted largely in the renewal of tuyere caps and grate bars. The weights of all the parts renewed were added together and found to be an average of 2,060 lbs. per boiler for a period of 1,333 hours of service. We have then for the weight of metal replaced per HP. per year $\frac{2{,}060 \times 8{,}640}{1{,}333 \times 517.5} = 25.8$ lbs. This, at 3 cts. per lb., represents $0.77 per year.

The data from which the cost of these repairs is computed applies to an interval of 15 months in the case of the Roney stokers, and three months in that of the Ameri-

*The American Stoker was illustrated and described in Engineering News, Vol. July-Dec., 1895, p. 55, and Vol. Jan.-June, 1896, p. 6.

*Attention is called to the fact that this small gain in economy of the American over the Roney stoker was obtained in the face of harder firing due to unequal proportion of grate and heating surface in the two boilers stated above.—Ed.

can stokers. In the former, the interval is sufficiently long to establish a close approximation to the true amount of repairs during the life of the stokers. In the latter, however, the interval is too short to determine the average cost for regular service, and furthermore, it does not cover repairs to the driving mechanism. It applies, also, to a period of time when the firemen were becoming familiar with the handling of the stokers and learning the best method of operating them to secure a minimum of repairs. With the general knowledge the experts have of repairs to stokers of this kind on other installations, it is believed that the item of $0.77 is greater than the average cost would be in regular service.*

The cost of repairs on the American stokers which must actually be borne by the General Electric Company is fixed by the contract for a period of two years, and cannot exceed 5% of the cost of the installation. This, reduced to the HP. basis, amounts to 12.5 cts. per HP. per year as against the above 77 cts. It seems proper to give due consideration to both these figures for cost of repairs.

LABOR.

The number of firemen and helpers employed per day of 24 hours with 1,500 HP. of each kind of stoker, on the basis of the tests of June 18 and 19, is 2 firemen and 2 helpers. Their wages per day are $1.75 for the firemen and $1.25 for the helpers. The cost of labor, therefore, per day of 24 hours is $2 \times \$1.75$ plus $2 \times \$1.25 = \$6$, and the cost per HP. per year is $\frac{6 \times 360}{1,500} = \$1.44$. We consider that the labor is on an average the same for both stokers. The labor is of different character. In the Roney stokers, according to the practice of the firemen during the test, there is continual attention and exertion required, consisting of poking the coal in the hoppers, poking the coal through the corner doors, and spreading it over the grate, slicing the fire through the grate from beneath, hoeing out the coal which falls down through the grates and shoveling it back into the hoppers, and dumping the ashes and clinkers from time to time from the lower grates. This is all comparatively easy work, although continuous. In the American stoker the poking of the fire is only occasionally required. On the tests of June 19, the round of the whole plant of three boilers (12 doors) was made once per hour and occupied above 5 minutes of the fireman's time. During the remaining time, no attention is required except to keep the hoppers filled from the chutes and adjust the speed of motors and fan. When the fires are cleaned, however, the work required is most severe. It not only requires great muscular exertion on account of the clinkers adhering strongly to the brick work from which they must be removed by the aid of a heavy slice-bar, but the work is exceedingly hot while it lasts.

On the whole, there is little to choose between the average amount of labor required in the operation of either stoker.†

FIXED CHARGES.

The fixed charges for the two types of stokers is the same in each case. The cost of either is $2.50 per HP. erected,‡ and we have taken the fixed charges for interest, depreciation, etc., at 15% per annum. This amounts to $.15 \times \$2.50 = .38$ per HP. per year.

These various costs are summarized as follows:

Costs per HP. per year..	American stokers—Repairs according to 3 mos. record on log book.	American stokers—Repairs guaranteed in contract.	Roney stokers.
Cost of coal.....	$34.95	$34.95	$35.76
Cost of repairs	0.77	0.12	0.48
Wages of firemen & helpers.	1.44	1.44	1.44
Interest and depreciation....	0.38	0.38	0.38
Total cost per HP. per year	$37.54	$36.89	$38.06

From the above table, it will be seen that the cost of steam is less with the American stoker than with the Roney stoker. The difference is $0.52 per HP. per year, or 1.4% if the repairs are based on the 3 months' record, and $1.17 per HP. per year, or 3.1% if based on the guaranteed amount. In point of relative economy, therefore, the guarantee of the American Stoker Company is fulfilled.

It should be noted that the repair items given in the summary apply to continuous service of the stokers 360 days per year, 24 hours per day, which is far beyond the requirements of ordinary work.

CONCLUSION.

Finally, our conclusions respecting the fulfillment of the four guarantees stipulated in the American Stoker Company's contract are as follows:

1. The stack is practically smokeless, as required.
2. The evaporation per pound of dry coal exceeds the stipulated 11.5 lbs.
3. The capacity developed is above the 33⅓% excess required.
4. The American stoker generates a net HP. of steam at less cost than the Roney stoker, and meets the guarantee.

All of the American Stoker Company's guarantees are therefore fulfilled. Respectfully submitted,

J. E. Denton,
Signed Dean & Main.
George H. Barrus.

A COMBINATION METALLIC GASKET FOR FLANGED JOINTS.

The novel metallic gasket shown in the accompanying sketch, consists of a ring of lead or very soft alloy surrounded by a ring of annealed copper wire, the lead ring being about twice the diameter of the copper ring. When the gasket is put in place between pipe flanges and the bolts are screwed down, the lead is flattened between the iron surfaces and flows into the most minute crevices and corrugations of the iron, while the copper ring prevents the lead from working out of the joint entirely, or from being blown out by the internal pressure. While a copper gasket alone makes a good joint between faced surfaces, the gasket illustrated is claimed to give good results with rough flanges, as the lead adapts itself to every inequlity in the surface like a rubber gasket, but does not lose its life and elasticity as the rubber gasket does.

A Combination Metallic Gasket.

This gasket has been placed on the market by the Merwarth Metallic Gasket Co., 107 Liberty St., New York city.

THE WATER-POWER PLANT of the Ottawa Electric Co., at the Chaudiere Falls, is ready for operation. The power-house is situated near the electric railway power-house on Head St., Ottawa. Like this latter, it is a brick and steel structure throughout, the foundations resting on solid rock. The power installation consists of three sets of main generators, and two sets of exciters. Each main generator unit is composed of three turbines 39 ins. in diameter, direct connected to one generator. Each exciter unit comprises two 15-in. turbines direct connected to an exciter dynamo. The total capacity of the station is 4,000 HP., and the current will be used for lighting and general power purposes in the city. The present steam power plant of the company will be retained as a reserve station.

TRAMWAY AND OMNIBUS TRAFFIC IN PARIS FOR 1900 is reported upon in "Le Genie Civil" Oct. 19. The number of passengers transported by the Compagnie Generale des Omnibus was 318,977,000, as compared with 280,505,000 in 1899. This increase, of course, is largely due to the Exposition. The total receipts last year were $11,465,800, an increase of $1,305,600 over 1899. In 1900 this company equipped the following lines with mechanical traction: With compressed air, the Auteuil-Madeleine line, the La Muette-Rue Taibout, Passy-Hotel de Ville and Montrouge-Gare de l'Est lines; with electric accumulators, Louvre-Vincennes and Louvre-Cours and Vincennes lines; with the Purrey steam system, the Bastille-Porte Rapp line. The latter system is being installed on the Lyon-Place de l'Alma line. The accumulator system on the Louvre-Vincennes line is not giving satisfaction and the Prefect of Police has notified the company that it must make important changes in material and method of operation. In comparing the expense of omnibus, horse tramway and mechanical traction, they find that mechanical traction is more costly; but it is also more productive. The receipts per vehicle—kilometer are—For omnibus, 1.135 francs; for horse tramway, 1.339 francs, and for mechanical traction 1.345 francs.

THE ELECTRICAL BURNER FOR BLAST FURNACES.*

By F. L. Grammer, M. Am. Inst. M. E.†

In these days, when anthracite is less extensively used as a blast furnace fuel than it was a generation ago, and managers endeavor to maintain regular and known ore mixtures, the "freezing" of tuyeres, cinder notch or iron notch is infrequent; and, consequently, the oil burner or "kerosene blowpipe" is seldom employed, and furnace foremen have to a considerable degree forgotten their former cunning and persistency in the use of the drill and sledge. Still, in starting new or abandoned plants with untrained labor, and in running some of our large 100-ft furnaces, slips, resulting in very cold furnaces, may occur even under experienced managers.

During my superintendence of the Cleveland, O., blast furnaces such a misfortune, owing to a dearth of trustworthy foremen, was experienced, and our electrician Mr. Thomas Martin, proposed to open the tuyeres and cinder notch by means of the heat of the electric arc. We have heard that the surface cracks or marks developed in rolling heavy plates have been closed by electric welding, as by a soldering iron, and also that an electric burner has been employed at some German blast furnaces; but the experiment was quite novel to us, and I think it constituted one of the first, if not the very first, successful application of this device for the purpose named in the United States.‡

In the construction of the circuit, we attached one wire to a pipe, feeding a cooling block of the furnace wall, some distance from the point where the burner was applied. The current from this wire passed either through the crucible or through the circumferential shell. The other wire, after running through a resistance coil immersed in a barrel of water, was attached to clamps holding the carbon, the latter being inserted in an iron pipe, provided with a wooden handle, and applied at the desired point by the goggled operator.

Our first experiments were not very successful. We used 1.5-in. carbons, 1.5 ft. long, not being able at the moment to obtain larger ones. Subsequently we had carbons made 4 ft. and 6 ft. long, and with these we burned a hole through 18 ins. of cold iron in five minutes. A current of from 400 to 500 amperes did the work, but 1,000 amperes (at 80 volts) gave better results. Our two dynamos were General Electric, with 110 K-W. capacity and 220 volts. We reduced the voltage by means of a resistance coil of German silver wire.

The results were so satisfactory that permanent wires were strung up to the furnaces,** and "hard holes" at tapping time, requiring slackening of wind, are now an evil of the past.

Water blocks sometimes leak and flood a side of a furnace, closing several tuyeres and causing one-sided working. But by putting blanks on the penstocks temporarily out of use the blast can be kept on the furnace while the closed tuyeres are burned open. Several furnaces on the lake front used it successfully, after hearing how it had assisted us.

The electric current employed is not dangerous to the workman, and the apparatus, unlike the oil blowpipe, is always ready for service. It can be applied instantly to a black, cold surface without the need of any blast pressure—a boon which will be appreciated at single stacks, where the freezing of the tuyeres may have made it

*A paper to be read at the Mexican meeting of the American Institute of Mining Engineers.

†Gen. Supt. Blast Furnaces, 19 Block St., Pueblo, Colo.

‡The principle was very clearly stated in 1891 by Prof. J. W. Langley (Trans., xx., 255), who said that in the course of experiments upon fusion in an electric arc furnace it happened on several occasions that the arc from the end of a carbon rod struck squarely in the center of a lump of steel about as large as a hen's egg, and that "in a very few seconds that arc would bore a hole through that piece of steel, the corners of the steel being still so cold that, when seen through the dark spectacles that one had to wear, they appeared to be black." I am informed that a similar device has been used by safe robbers.

**The low potential requires a heavy copper wire.

(*Concerning the repairs on the American stoker, the manufacturers have furnished us with the following statement.—Ed.): "The repairs mentioned as being required for the American stokers consisted almost entirely of tuyere caps, these being small castings provided with air openings through which the air emerges into the fuel. These tuyere caps at Schenectady were made of common cast iron, whereas they should have been and are now supplied of open-hearth cast steel, which probably has 20 times the lasting qualities under heat as that of cast iron. At the time this test was made and four months before, during which time the logs alluded to were prepared, it was impossible to get steel castings from the foundries. They were months, and in some cases years behind on their orders. Furthermore, it can readily be understood that the difference between replacing a set of tuyere caps a day or two before the test was finished and consequently having the cost of same charged against the American stokers and allowing the old set to remain until after the test would, in the short period during which the log was kept (namely, three months) increase the charge very considerably."

†(The following comment on the clinkering of the American stoker is furnished by its manufacturers.—Ed.): "The heating surface in the Stirling boiler under which the American stokers operated at the same rating as applied to the B. & W. boiler under which the Roney stokers operated, was 7¼% less per H.P., hence stronger and hotter fire was required to keep up the rated HP. of the Stirling boiler. Again, the grate surface on the Stirling boiler was 84 sq. ft., and on the B. & W. boiler 84 sq. ft. also, while the B. & W. boiler was rated at 412 HP. and the Stirling at 517 HP., or 23% more than the B. & W., hence harder and hotter firing was required to maintain the rated HP. Briefly, the Stirling boiler and American stokers were handicapped by the higher ratio of heating surface by 7¼% and smaller grate surface by 23%. These facts supply sufficient reason for the appearance of the clinker alluded to, and also the 54 door openings on the American as against the 45 on the Roney, as shown by the test. Recent improvements in the American stoker, including shaking and dumping grates, eliminate almost entirely the use of side doors, besides reducing the amount of labor required. It is fair to presume the experts would not have judged the two stokers to be on the same basis as regards labor required had they considered the disproportion of grate surface referred to above."

‡(We are informed that this cost in the case of the American stoker includes in every case the complete forced draft equipment used in connection with the stoker installation. By the use of the forced draft the engineer can force the boilers to the highest practicable capacity beyond their commercial rating.—Ed.)

difficult to get the necessary pressure by affecting the gas supply to the boiler house.

The saving in oil, worn-out men, drills and time commends this simple and effective burner as the best. We may say of this apparatus what used to be said of a dress coat or a pistol—that "it is not needed often, but when it is needed it is needed awfully!" Plants not equipped electrically can use the power of a neighboring municipality or other works, employing a rotary transformer to obtain the desired current. Both the holder of the burner and the curious spectators should wear the darkest glasses, such as are worn by heaters, or 12 hours of great sufferiow will be the penalty.

STEAM SHOVELS FOR TRENCH EXCAVATION.

In the excavation of narrow and deep trenches for sewer, water or gas mains, etc., particularly in city streets, hand labor or special excavating machines must be employed, and machines for this class of work have been described and illustrated in our issues of July 12, 1900, and Sept. 19, 1901. For wider trenches, however, such as those for large trunk sewers, drainage ditches, etc., steam shovels may be used, and we have recently taken occasion to inquire into the use of steam shovels for this class of work.

Perhaps the most interesting piece of work upon which this method of excavation has been employed is that of the main sewer under the yards of the Chicago Transfer & Clearing Co., whose switching and terminal yards and plant at 63d St., Chicago, were described in our issue of June 13. A tract of land 4,000 acres in area will be occupied by the yards, warehouses, etc., and for the drainage of this land a main sewer has been built, 18 ins. to 9 ft. in diameter. For diameters up to 30 ins., the sewer is of pipe, but for 36 ins. and upwards it is of monolithic concrete construction. The contractors for this work were Nash & Dowdle, of Chicago, who employed two styles of steam shovels for the trenching, one made by the Vulcan Iron Works Co., of Toledo, O., and the other by the Bucyrus Co., of South Milwaukee, Wis. Fig. 1 shows a view of the 75-ton Vulcan machine at work on this trench. The machine has its trucks frame on the turntable. The hoisting engine has cylinders, 10 × 13 ins.; swinging engine, 8 × 10 ins. The boiler is of the locomotive type, 5 ft. diameter, 12½ ft. long. The boom seen behind the steam shovel is that of the backfilling machine, which handled a drag scraper traveling laterally across the trench, filling it from the heap of excavated material.

The excavation comprised 2 ft. of black soil, followed by 12 to 20 ft. of blue and chocolate clay, with more or less water seams. The accompanying table shows the character of the work done, and for this we are indebted to Mr. A. W. Swanitz, Chief Engineer of the Chicago Transfer & Clearing Co., who is shown in the illustration at the side of the machine, with a roll of plans in his hand.

TRENCH EXCAVATION BY STEAM SHOVELS.

	Diameter of sewers			
	84 and 90 ins.	48 ins.	42 ins.	36 ins.
Length of trench cut, ft.	2,913	3,099	1,273	5,090
Width " " " "	10	7	7	6
Depth " " " " max.	*10	15	15.5	13.8
" " " " min.	..	6	14.5	9.6
Make of steam shovel	Vulcan	Vulcan	Bucyrus	Bucyrus
Capacity of bucket, cu. yds.	1½	1½	¾	¾
Length of dipper arm, ft.	36	36	36	36
†Ave. progress per day, ft.	69.8	98	85	..
†Ave. excavat'n day, cu. yds.	492	345	330	293

*Average. †10 hours.

In regard to the use of steam shovels for this class of work, the Vulcan Iron Works, Toledo, O., write us as follows:

We build steam shovels for trench work of four different sizes and capacities, and the diagram, Fig. 2, shows the dimensions of the trenches which these four machines will dig. They will dump the material from 14 to 24 ft. away from the center line of the trench, according to the size of shovel used. The sizes and capacities of the machines are as follows:

Weight of shovel.	Trench Width.	Trench Depth.
40 tons	6 ft.	12 ft.
50 "	9 "	15 "
65 "	12 "	18 "
75 "	15 "	20 "

It is not practicable to excavate a trench under 5 ft. wide with any steam shovel, or over 15 ft. wide and 20 ft. deep. The shovels used for this class of work vary in capacity from 800 to 2,000 cu. yds. per day, according to the class of material to be handled. Of course, they will not handle as much material where it is mixed with cemented gravel, shale rock, hard blue clay, or where it is full of bowlders, as they will of the ordinary earth free from such materials. The shovels when shipped from the works are mounted on standard railway trucks, which are removed at destination and replaced by skids which are in turn mounted on regular house rollers. The shovel is then run directly over, or straddle of the place where the trench begins, and is then ready to go to work. One of the great features of using a steam shovel of this kind for trench work, is that at no time is it necessary to have but a small portion of street torn up, furthermore the brick masons, etc., can follow close in the wake of the shovel, and do their work; in fact, they even work right under the shovel while it is in operation. The shovels are self-propelling. They are equipped with dippers specially constructed for this class of work, as the ordinary steam-shovel dipper cannot be used.

These trench steam shovels are so constructed that if the owner has other work beside his sewer or trench work to do, he can easily convert the trench shovel into a shovel that will do any ordinary excavating, by simply replacing the standard railway trucks under it and equipping it with the ordinary dipper and dipper stick. We have quite a number of these shovels at work in different parts of the country. One of them, at Summit, Ill., weighs about 50 tons, and dug a trench 12 ft. wide, 18 ft. deep and handled between 1,600 and 2,000 cu. yds. of material per day. The material handled was clay.

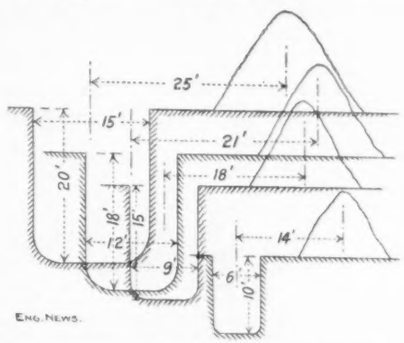


Fig. 2. Sections of Trenches Excavated by Steam Shovels of the Vulcan Iron Works Co.

This firm also builds a 50-ton shovel for sewer work. This has a boom 23 ft. 6 ins. long, and a dipper arm 30 ft. long. It is equipped with a hoisting engine with cylinders 9 × 12 ins., and a swinging engine 5 × 6 ins. The locomotive boiler is 4 ft. 8 ins. diameter and 9 ft. 4 ins. long. In addition to the two classes of steam shovels above mentioned, the firm also equips its Little Giant 20-ton traction wheel steam shovel, so that it can be used for sewer work. One of these shovels has recently been at work near St. Louis, Mo.

Steam shovels of 45 tons weight, built by the Bucyrus Co., of South Milwaukee, Wis., have been used for sewer excavation by Cogan & Pound, contractors, of Chicago. These machines are mounted in the same way as the one already shown, and are very similar in general construction, but have no solid web plate for the outer end of the boom, beyond the bearing for the dipper handle. A long dipper handle is used, and a dipper or bucket of special construction, in which the cutting edge is the widest part, so that the lugs and fastening for the bail are clear of the sides of the trench. Such a machine is capable of digging trenches up to 12 ft. in width and 20 ft. in depth. The smallest steam shovel built by the Bucyrus Co. is a 12-ton machine, with a bucket of ½-cu. yd. capacity, and the width of trench upon which this is used should be not less than 5 ft.

The King ditching machine, built by the Marion Steam Shovel Co., of Marion, O., has also been used by Chicago contractors for large sewer trench work. The trenches were 10 or 12 ft. wide and 10 to 12 ft. deep. This machine is a "dry-land dredge," dragging itself along on the ground by means of two wire cables run ahead and fastened to anchors, the cables being hauled in by large drums on the dredge. Water in the trench, to a depth of 24 ins., will do no harm, but the machine will not float. The contracting firm of Gahan & Byrne, of Chicago, informs us that it used the King machine for excavating the top 14 ft. of the trench for the Robey St. sewer, and would certainly use such a machine on any similar work of equal magnitude, as there is no question but that it would be cheaper than hand labor. The use of steam shovels for excavating the trench for the Wentworth Ave. sewer, Chicago, 10½ ft. inside diameter was described in Engineering News, 1894, II., 292. This trench was 16½ ft. wide between the piles supporting the caps on which the steam shovel rested.

FIG. 1. STEAM SHOVEL EXCAVATING SEWER TRENCH FOR THE CHICAGO TRANSFER & CLEARING CO. A. W. Swanitz, Chief Engineer, Chicago, Ill.
Nash & Dowdle, Contractors, Chicago, Ill. Vulcan Iron Works Co., Builders, Toledo, O.

removed, and is mounted on a heavy timber framing, stiffened by truss rods, as shown. The ends of the cross timbers rest on sills on either side of the trench, and these sills are carried on wooden rollers on a plank runway. The machine is thus placed directly over the trench, and hauls itself ahead by an anchored cable. The boom, 28 ft. long, is pivoted to the turntable, and consists of two fish-bellied plate girders, the head of the boom being supported by tie rods from an A-

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Unification and municipal control of the street railways of Chicago are the two chief points aimed at in a suggested outline for a renewal of the various street railway franchises of Chicago. This outline has been prepared by Mr. Geo. C. Sikes, Secretary of the Committee on Local Transportation of the City Council. The unification would largely consist in joint power and track service, and in a proper transfer system. The municipal control would involve all the regulations necessary in the interests of the traveling and general public, and would be ensured by specific franchise provisions, and, in some respects more important still, by purchase clauses in the franchises under which the city could, at any time after ten years, buy the railways at actual cost, plus 5 per cent. on the investment. Mr. Sikes rightly states that what the city wants, first of all, is first-class service, and that while companies enjoying valuable street railway privileges ought to pay for them in "either money compensation or reduced fares" to secure "either at the expense of good service or to the derogation of the power of the public to exercise effective continuing control would be a serious mistake." We commend this line of policy to other cities than Chicago, and to those dealing with other than street railway franchises.

The serious bearing of water waste upon water purification and upon municipal financiering in general is brought out in the annual report of General Gillespie, Chief of Engineers U. S. A., with reference to the conditions at Washington, D. C. The consumption and waste of water in Washington on June 26 was found to be 53,960,998 gallons, while measurements each month indicated a daily average of 49,075,940 gallons for the year. The June figures, on a basis of 279,293 population for the district, give a per capita consumption and waste of 193 gallons, or a probable waste at least as great as the actual use. It is estimated that the cost of operating the new filtration works will be $6 per 1,000,000 gallons, which, at the present rate of consumption and waste, amounts to $300 a day, or $110,000 a year. If the waste is continued, a second conduit from the Great Falls of the Potomac will be required in about twelve years. The alternative is a meter system, which, it is thought, would cut the consumption down to 100 gallons a day.

Aside from the usual reasons for cutting down water waste, a special obligation rests upon those responsible for the administration of the affairs of the District of Columbia. The public works of a national capital should be, both in design and operation, examples for other municipalities throughout the country to emulate. In street construction and maintenance Washington has long been a model for the cities of the continent, but in the character of its water supply and the prevention of water waste it has been quite the contrary. After enduring for years a water supply laden with mud, and certainly not free from disease germs, there is at last a prospect of pure water. But the completion of the purification works might be hastened, and large sums of money saved for other needed municipal improvements, if the water waste, and thus the cost of both filtration and increased means of supply, were cut down.

The Pan-American Exposition, which came to an end on Nov. 2, has been an unqualified success in every respect save two, the attendance and the net financial results. These exceptions are so important, however, that it is a fair question to ask whether an exposition which fails in these respects can be called a success.

Exact figures are not yet available, but the general financial results at Buffalo are well enough known to point the moral. The total attendance at the Exposition was about 8,200,000, including passes. Roughly, this is about half the attendance which the managers of the Exposition expected, and in fact accident insurance was carried by the Exposition company on 16,000,000 paid admissions. The total expenditure of the Exposition company is said to have been in round numbers about $10,000,000, and it will be seen that when the passes and special rate tickets are allowed for in the total admissions, the total revenue from the sale of tickets must fall, probably, below $3,500,000. To this sum is to be added, of course, the revenue from the sale of concessions, amounting, very likely, to nearly as much as the revenue from tickets; but the final result is a net loss of between three and four million dollars. The subscribers to $2,100,000 of Exposition stock get nothing. The holders of $500,000 of second mortgage bonds get nothing. The contractors who did work for the Exposition lose $1,000,000 or so, according to reports, and it appears to be doubtful whether even the first mortgage bondholders will get back all their money.

It must be admitted that in some respects the Exposition was peculiarly unfortunate. The bad weather of last spring delayed its completion, and discouraged attendance. The national tragedy of which it was the scene in September, distracted public attention just at a time when the record of ticket sales was rising higher every day. Yet when every allowance is made for these drawbacks, it is only too evident that the financial failure of the enterprise was inevitable.

It may well be asked, do great expositions pay? Is the indirect benefit sufficient to offset the direct financial loss which experience has abundantly shown almost invariably results? Is the money spent in rearing a costly city of temporary buildings to endure for a single brief summer really well and wisely expended? Is there enough of public amusement and recreation and instruction given in such great expositions to make their continuance worth while?

These questions are too far-reaching for extended discussion here; we can only touch on some of the pregnant facts which give food for serious thought. There is a general consensus of opinion that at certain intervals in human progress a general exposition of all arts and industries serves as a milestone of achievement and performs a useful service in public education. The Crystal Palace, the Centennial, the Columbian and the two great Paris Expositions have by the scope and historic influence fully justified themselves. Can we say as much for the minor expositions? How many have been held in the United States since the Columbian Exposition closed, and who now remembers even where or what they were?

It does not follow, of course, that a local exposition may not be well worth while, even though it may not achieve national fame. In every such case a comparison must be made between the cost and the return, before one can form an opinion as to whether the money was well expended. It is on this very point, simple and self-evident though it seems, that exposition managers most frequently err. There is a tendency to spend money without limit at a stage when the reputation of the exposition has to be made, and trust that increased expenditure will give even larger increase in attendance. This was the case with the managers of the Pan-American. They spent $10,000,000 on an exposition, when they might have made one almost as excellent for half the money. The superabundance of decoration on buildings and the minor architectural effects represented a large outlay and did not represent a corresponding return in increased attendance—nor were they even worth while, even admitting their excellence, for the education of the public in matters of taste.

Are we not going to wasteful extremes in lavishing money on evanescent paint and plaster cities whose life is only a few short months? The Buffalo Exposition cost the exposition company, as stated above, $10,000,000 in round numbers. Expenditures by "side-shows," and other concession holders, by states, by exhibitors, by builders of cheap hotels, and others who take part in the entertainment of the visitors will doubtless double this amount. Now, $20,000,000 is a huge sum of money, even in these days. What a large measure of public benefit $20,000,000 would work if it were invested in something permanent—libraries, picture galleries, parks, museums, playgrounds, sanitariums, hospitals.

We do not say expositions are not worth while. Perhaps they are—some of them at least; but let them not multiply too thickly, and let reasonable economy control in the construction of things designed to endure for only a few brief months.

It seems strange that a suburb of New York, with a population of over 11,000 people, and the reputation of being one of the most wealthy and refined communities in the country, should continue year after year without a sewerage system. But such is the case at Morristown, N. J. There are indications that this and other sanitary neglects on the part of the town are retarding its growth. Its population in 1880 was 5,418; in 1890, 8,156; in 1900, 11,267. The increase from 1880 to 1890 was 51 per cent., and from 1890 to 1900, 38 per cent. Compared with these figures, Montclair, a community in many respects similar to Morristown, but nearer to New York, had populations of 5,147, 8,656 and 13,962 in 1880, 1890 and 1900, respectively, showing an increase of 68 per cent. between 1880 and 1890, and 63 per cent., or only a slight falling off, in the decade just passed. A public water supply was introduced in Montclair in 1887, and a sewerage system in 1894. Waterworks were built in Morristown in 1799, or 102 years ago, but it is still without a sewerage system. Of course, the lack of a sewerage system does not wholly account for the relatively slow growth of Morristown in recent years, but it undoubtedly has had its effect. The time has come when any community, or street, or house, without modern sewerage facilities is at a disadvantage on that account. This is particularly true in suburbs of large cities, possible newcomers to which are very largely attracted or repelled by the sanitary conditions of the town.

THE END OF PROSPERITY FOR THE SHIP OWNER.

The turn of the tide has come in the ocean transportation business, and the industry in which prosperity has ruled to an amazing degree for the past seven years is now entering upon a period of hard times. There is a common impression in the United States that the ocean shipping business is exceedingly profitable; but the real fact is that in few industries is the net return to the investor so small, taking good years with bad, and considering the risks involved. The reason for this is plain. The business of transportation in the high seas is open to free international competition. The shipper of goods in foreign trade may have vessels offered him sailing under half a dozen different flags, each eager to secure the business and ready to bid for it against each other. Of course, the reverse may also prove true, and in times and at places where the freight offered is in excess of the vessels in sight to move it, the ship owner has the advantage, which he, of course, improves.

Even more than most other industries is the shipping industry subject to alternations of prosperity and hard times. In the early '90's there was a long period of dulness. Ocean carrying capacity was in excess of the demand; competition reduced rates so low that there was little profit left for the ship owner; many vessels were put out of service by their owners in preference to running them at a loss.

Of course, as always happens, the pressure did not fall on all alike. The newest vessels fitted with most economical engines, able to carry goods at lowest cost, and so safe and seaworthy that rates of insurance were low, could keep running at a profit, while the old tubs had to lie idle or were broken up. Under such conditions, of course, the building of new ships fell off. In a few years the steady growth of international trade increased the demand for shipping, and raised the rates of freight. Many causes conspired to this end. The development of new countries, such as the wheat-growing region of Washington, the timber lands of the Cascades, the gold deposits in South Africa, gave a stimulus to the shipping business in 1896 and 1897 which began to help ship owners to make fair profits. Following this came the discovery of gold in the Klondike and the rush thither; and following that, and more important than all else combined, the war between the United States and Spain, and the South African War. Out of the former came the Philippine insurrection, with its consequent large demands on Pacific shipping. The sudden great call for vessels for Government service, made the total demand for shipping in excess of the supply, and sent ocean freight rates skyward. Every vessel that could float was pressed into service, and for the last three years the ship owner has had a period of glorious prosperity.

Sentimental considerations have played an important part, too, in the increase of shipping. Commercial expansion is the order of the day, and nations everywhere are laying stress on the increase of their merchant marine. Germany, England, the United States, France and even Japan have been turning their attention more and more to the business of ocean shipping. The shipyards of the world have been working to their fullest capacity to turn out vessels for owners who seemed to think the era of high freights would never end.

But now comes the inevitable reaction. It is suddenly discovered that shipping has expanded far beyond the needs of international trade, and in the competition for charters, prices have gone down with a rush. According to the London "Economist," vessels are now carrying grain across the Atlantic for 1d. (2 cts.) per bushel, and have to make the return voyage in ballast at that. It quotes the "Shipping Gazette" as stating that in scarcely a single trade, even with the most economical vessel, is it possible to make a profit. The worst feature of the case for the ship owner is that this is apparently no temporary condition, but one which must continue until supply and demand are more evenly matched. But the vessels which were ordered many months ago, while the wave of prosperity was at its height, are now being launched to add to the surplus of idle vessels and the shipyards are still full of orders for months to come. Under these circumstances there seems no escape from the conclusion that we are at the beginning of a long period of low rates for ocean freights.

Here, as in other fields, it is proving true that extreme competition begets combination. There have been enormous changes in the shipping industry during the past dozen years. The old-time tramp steamer, going from port to port for its cargo, wherever market conditions invited, is being driven out of business at the larger ports by the huge freight steamers owned by shipping companies and run regularly on a definite route. Between these rival lines traffic agreements are almost as much a matter of course as they are between railway companies. They are limited, of course, by the fact that if rates are pushed too high, the large shipper can charter a tramp to carry his goods, but within this margin their power is unrestricted.

These radical changes in the economic situation of the ocean-carrying trade ought to receive most careful attention at the hands of Congress when the ship subsidy bill is again brought before it, as it undoubtedly will be at the approaching session.

It is true, on the one hand, that a subsidy will be more necessary than ever to induce Americans to invest in ocean shipping in competition with vessels of other nations. It is true, on the other hand, that the exporter who sends abroad the products of American farms, mines or factories can now obtain as favorable rates and accommodations from foreign vessels as he can possibly ask for. It is also true that while the export trade is doubtless better served by ships of the regular lines than by the tramp steamers, no subsidy can be given to regular lines without increasing still further their power to create and maintain a monopoly in the carrying trade. In other words, they are quite certain to continue to carry the business which they control, subsidy or no subsidy; and in the absence of competition anything paid them from the Government treasury will simply increase by so much their profits, and will not be returned to the public in the form of lower freight rates.

Certainly, if funds from the public treasury are to be used to stimulate the carriage of goods in American vessels, some practical public benefit ought to be received from it proportionate to the amount expended. It makes no difference to the American farmer, or miner or worker in the shop whether the product of his labor is sent abroad in a vessel registered under the American flag or under the British or Norwegian or Danish. What he wants is the lowest rates that international competition will secure for the ocean carriage, so that as large a margin as possible may be left for him.

LETTERS TO THE EDITOR.

Concerning Changes in Bridge Design.

Sir: After again reading your editorial of Sept. 26, entitled "Some Thoughts Concerning Changes in Bridge Design," I concluded that the subject is of such importance that one or two more thoughts might to advantage be added and a few points discussed.

That the increasing weight of rolling stock on railways and the heavier character of traffic on streets and roads has not been the only cause of the short life of our early bridges is true; but I cannot agree with you that rust—with one exception to be stated further on—has been a potent factor in the case. The other powerful contributing cause of their removal has to be looked for in another direction, namely, in the shortcomings of the designer, or, rather (for far be it from me to speak slightingly of the pioneer builders of those days), in what we now, in the light of our accumulated experience and more thorough knowledge of materials through the constant use of the testing machine, have a right to consider as shortcomings.

The use of cast iron alone would have brought about an untimely death of many of the old bridges. Lack of stiffness due to the use of suspended floor beams and ineffective lateral bracing, inaccessibility to painting, excessive number of adjustable members, and last, but not least, faulty proportioning of details, have to be added. To illustrate the latter point: We still have in this city an otherwise strong bridge, built by the Keystone Bridge Co. in 1876, with 3-in. pins and 8-in. eyebars in the bottom chords, which brings to my recollection the astonishing fact that in every joint of the main arches of the justly celebrated Eads bridge (built 1869-74) 4½-in. steel pins connect 10-in. wrought-iron eyebars with the tubes. Without an increase in the loads and if the engineer of those days had our stock of experience to draw upon, most of the earlier bridges—with the exception mentioned above—might, with little care, be in use to-day. The fact that every bridge failure in this country during the last 30 years, whenever it has been possible to account for the same, has to my recollection been accounted for by derailment, washout, injudicious use of cast iron, overloading, lack of rigidity, etc., and not by corrosion, might be cited as a partial proof.

To give one example: A few years ago I took part in the examination of one of the few original Mississippi River bridges, built about 1870 and still in use. It is a combined highway and (single track) railroad bridge, and had to all appearance received little attention as to painting; the painting had, in fact, been principally applied above the floor, the use of paint having been considered—as the farmer generally considers it—an ornamentation, not a means of preservation. Still, after carefully going over the details and noting the weak points (and they were numerous), the thought of a serious deterioration of the old structure by rust was never entertained. With the exception of the closed Phoenix columns, and even here the effect of rust was small, every member of the bridge was not more damaged by rust than the day the bridge was erected, 30 years ago. Rust eats its way slowly—in the country.

And now I come to the exception, mentioned twice: Rust (taking the word in a broad sense as the effect on metal of atmospheric influence and of obnoxious gases) acts very, very fast in large cities, particularly in the large western cities, with their damnable soft coal smoke. If proofs of this statement were needed, I could send Engineering News a beautiful assortment of photographs of members of our city bridges, from 25 to 7 years in use, with web sheets which look as if a brisk fire of artillery had played on them, angles and plates worn to the thickness of a knife edge, pins reduced ½-in., ¾-in. and 1 in. in diameter between the bearings, rivet heads, which originally had been semi-spherical, now looking like what in the technical phraseology of the day (see Carnegie's "Pocket Companion") would be called "flattened," or "countersunk and not chipped," and joints wide open between the rivets, pressed apart by a curious compound of scale, rust and dirt (and hadn't we been careful to specify and to insist on it "that the surfaces coming in contact shall be painted before being riveted together!"). But all this is too well known. It is enough to state the conclusion which every bridge engineer has reached and which has been stated of late by the Engineering News also, that our profession cannot point with any particular pride to its solution of the problem of designing lasting structures, exposed to the gas and coal-dust laden air of our large cities. The protection by paint to which we had trusted, has disappointed us, and in cases where the smoke of locomotives reaches the metal directly, it has utterly failed. In the latter case no engineer is justified any longer to recommend the building of steel bridges without more lasting protection than paint.

(Here I may incidentally remark that my trust in wooden protective ceilings—and at the time it had been a source of considerable satisfaction to me to have introduced them in this city—see Eng. News, Oct. 26, 1899—has received a rude shock, when, during this summer's unbearable heat not less than 10 fires occurred on the wooden floors of our viaducts through sparks from engines, inside of one month.)

There is, however, something more to be said on the paint question. The Engineering News seems not to be familiar with the practice of this and probably numerous other cities, where painting is done, not by contract, but by day labor under a competent foreman. In St. Louis, at least, "the old paint is thoroughly removed" before a new coat is put on, and in our practice "the old paint is and can be removed by hand." The wire brush, the scraping knife, and the chisel are the tools required. It is true, this is not a cheap way of painting, the scraping costing more than one coat of paint and the total cost of labor amounting to five times the cost of the materials used. But the work is efficient, and unless done in this manner is hardly worth doing at all.

Yes, the editor is right: "Engineers are getting tired of paint." But I may be excused in making the statement that this tired feeling would prevail less generally if paint were bought on the same business principle as hydraulic cement is bought, i.e., no test no sale. The cement tests are made by the engineering force; to test paint the services of the chemist have to be called in, and the practice in this city has been for some years to buy the ingredients of the paint, subject to tests made in the chemical laboratory, and then to mix the same for the work in hand. This paint question is of the utmost importance, for, no matter how much its field of application within the future be reduced, it will always be with us and will have to be dealt with in the proper, business-like spirit.

That the small-span steel structure will give way to the concrete arch is no longer "a consummation devoutly to be wished"; it is an assured fact, and the work has already begun along our railroads and highways, with the exception, however, of those cases—and their excep-

tion has not been noted in the article which has called forth this communication—where lack of headroom and lack of space for massive piers and abutments exclude the arch.

It is very tempting to follow you into the field of concrete in its application to engineering structures, either as permanent protection to metal or as arch bridges; but, fearing that I have already taken up more than reasonable space, I will confine myself to the remark that I thoroughly agree with you in your advocacy of the 3-hinged concrete arch.

Yours truly,

Carl Gayler, C.E.

St. Louis, Mo., Oct. 26, 1901.

Proposed Changes on the Brooklyn Bridge.

Sir: In your number of Oct. 24 we find a criticism of our report which has the merit of discussing the bridge and not the authors of the report upon it.

Mr. Lindenthal thinks the real bending stresses and shears, in stiffening trusses between ends of stay system due to load and temperature changes combined, are larger than those given in our report and refers us for the calculation of temperature stresses to a paper written by him and published in Appendix D of the "Report of U. S. Engineer Officers, 1894," as to the maximum span practicable for suspension bridges.

In the calculations for a Hudson River Bridge, one of us had occasion to study the problem of temperature stresses in suspension bridges with three-hinged stiffening trusses. He consulted Mr. Lindenthal's paper, but found that his analysis was erroneous and gave greatly exaggerated results. The solution of the problem was therefore worked out independently and the calculation, with the proof for it, was incorporated in a report on the calculation of Hudson River Bridge. Mr. Lindenthal's calculation is in error in that he overlooks the fact that the stiffening trusses turn about the center hinge when the cables expand in consequence of increase of temperature and loads, thus forming an angle at hinge, and that this angle must be duplicated in the cables. His argument assumes that both stiffening trusses and cables form unbroken curves past the center hinge, both before and after deflection.

The temperature stresses in stiffening trusses of Hudson River Bridge amount to only about 4% of the stresses due to moving load, while calculation according to Mr. Lindenthal's method would make them over 25%. The correct method of calculating the temperature stresses in a three-hinged stiffening truss and the proof therefor is given in the following:

DETERMINATION OF STRESSES IN STIFFENING TRUSS FROM EXPANSION OF CABLE BY CHANGES OF TEMPERATURE AND VARIATION OF STRESS.

We build the bridge so that the cables form one parabola when the lower deck of bridge is fully loaded, the upper deck unloaded, at mean temperature; the moving load being in a mean position, assuming the stiffening truss rigid. If the temperature rises 60° the cables expand $\frac{1}{2,400}$ of their length, the saddles move toward the center of the bridge on account of the expansion of the back cables; the span center to center of saddles diminishes, and the length of cables between saddles increases, both of which changes induce a drop at center of span. If we neglect for the moment the deformation of stiffening truss produced thereby, and the change in length of suspenders produced by the slight change in strain in the same, we find that the two half spans of stiffening trusses turn around their end hinges and drop in center of span. The different points of cable drop the same amount as the points of stiffening trusses directly below them. If we take the lowest point of cable at mean temperature as origin of co-ordinates, with the axis of x horizontal and the axis of y vertical, we have, if h designates the y of cable above the end hinge of stiffening truss and l designates the span of stiffening truss, the equation of cable at mean temperature $y = c\,x^2$; we find (by letting $x = \frac{l}{2}$ and $y = h$)

$$h = \frac{c\,l^2}{4} \text{ and } c = \frac{4\,h}{l^2}; \text{ therefore, } y = \frac{4\,h}{l^2}\,x^2.$$

At highest temperature we have, if the drop at center of span is δ, a drop of each point of stiffening truss

$$= \left\{\frac{1}{2} - x\right\} \frac{\delta}{\frac{l}{2}} = \frac{l - 2\,x}{l}\,\delta.$$

Each point of cable will drop the same amount as the point of stiffening truss directly below; we have, therefore, the equation of lower position of cables:

$$y = \frac{4\,h}{l^2}\,x^2 - \frac{l - 2\,x}{l}\,\delta. \qquad (1)$$

We obtain the equation of this curve in regard to a new origin with new axes of x and y parallel to old ones by letting

$$y = y_1 - \left\{\delta + \frac{\delta^2}{4\,h}\right\} \text{ and } x = x_1 - \frac{\delta\,l}{4\,h}.$$

Introducing these values in above equation (1) it becomes

$$y_1 = \frac{4\,h}{l^2}\,x_1^2.$$

which is the equation of a parabola with axis parallel to axis of y, and vertex in origin of co-ordinates.

If we differentiate equation (1) and let $x = 0$, we obtain $\frac{d\,y}{d\,x} = \frac{2\,\delta}{l}$, this gives us the inclination of cables against the horizontal at center of span.

For the purpose of proving that the suspender pull is constant over whole length of half span, we consider the equilibrium of a piece of cable O B. The equation expressing the fact that the sum of all the vertical forces acting on O B is equal to 0 is:

$$V - H\,\frac{d\,y}{d\,x} - \int_0^x p\,d\,x = 0.$$

Where p is the suspender pull per lineal foot of bridge at any point of cable, H is the horizontal component of end reaction; V is the vertical component of end reaction.

If we differentiate the above equation, we obtain:

$$-\,H\,\frac{d^2\,y}{d\,x^2} = p.$$

If we differentiate the equation of parabola of cable twice, we obtain:

$$\frac{d^2\,y}{d\,x^2} = \frac{8\,h}{l^2}.$$

If we introduce this into above equation for p, we obtain: p = constant.

We find, therefore, that the suspender pulls, though they are changed from what they were by the drop of span in center through lengthening of cable, are still constant over the whole length of the span.

The cables of two half spans meet in center at an angle; the consequence is an upward pull acting from cables on stiffening truss at hinge. If H is the horizontal component of strain in all the cables, this upward pull is

$$S = \frac{4\,\delta}{l}\,H.$$

On each half-span of stiffening trusses an upward force

$$\frac{S}{2} = \frac{2\,\delta}{l}\,H,$$

therefore acts at center of main span. Since the forces now considered acting on stiffening truss are uniform over the whole length of the span, an end reaction equal to $\frac{S}{2}$ must act at each tower end of stiffening trusses; this will reduce the suspender pulls per lineal foot of bridge by an amount equal to $\frac{2\,S}{l}$. In other words, the effect of the drop in the center on account of expansion of cable, is that part of the load on the stiffening trusses equal to $\frac{2\,S}{l}$ per lineal foot does not go through the suspenders into the cables, but is carried by the stiffening trusses to center and end hinges, just as a uniform load on an ordinary span is carried to both ends by the trusses.

Let p = the pull in suspenders per lineal foot of bridge from all forces combined;
q = the weight of suspenders, stiffening trusses and suspender pull due to moving load, all per lineal foot of bridge;
w = the weight of cables per lineal foot horizontal;
L = span, center to center of towers;
l = span of stiffening truss; and
h = the versed sine of the cable.

Then we obtain by taking moments of all the forces acting on the cable around the lowest points of the cables:

$$\left\{\frac{w\,L}{2} + \frac{p\,l}{2} + \frac{S}{2}\right\}\frac{L}{2} - \frac{w\,L^2}{8} - \frac{p\,l^2}{8} = H\,h. \qquad (1)$$

We have from the foregoing:

$$S = \frac{4\,\delta}{l}\,H; \qquad (2)$$

and

$$p = q - \frac{2\,S}{l}. \qquad (3)$$

If the values of H and p, from equations (2) and (3), are introduced into equation (1), and the equation is solved for S, we obtain:

$$S = \frac{\delta\,[(w+q)\,L^2 - q\,(L-l)^2]}{2\,[(L-l)\,\delta + l\,h]},$$

or approximately,

$$S = \frac{\delta\,(w+q)\,L^2}{2\,l\,h}. \qquad (4)$$

The force per lineal foot of stiffening trusses acting downward at high temperature, due to change of temperature, is as before found $\frac{2\,S}{l}$. If we introduce for S the value from equation (4), we obtain

$$T = \frac{2\,S}{l} = \frac{\delta\,(w+q)\,L^2}{h\,l^2}.$$

Where T is the weight per lineal foot of bridge which would produce the same stress in stiffening truss as a rise in temperature of 60°, if the stiffening truss were an ordinary truss uniformly loaded and supported at both ends. This does not allow for the elasticity of the stiffening truss, on account of which part of the load T is distributed by cables, etc.

If the stresses from changes of temperature alone are wanted, then δ is the drop of cables in center of span due to changes of temperature alone.

With such shallow stiffening trusses as are used in the Brooklyn Bridge their elasticity and consequent deformation has to be taken into account, while in deep stiffening trusses it may be neglected.

We therefore calculated the amount of curvature in the stiffening trusses of the Brooklyn Bridge. This curvature diminishes the angle of cables at center of span and the consequent stresses due to the changes of temperature in cables as well as in stiffening trusses. In the Brooklyn Bridge these stresses are largely increased by the action of the stay system, which greatly reduces variation in position of cables as far as it extends, and thereby increases them at center of main span. It also reduces variation in the position of stiffening trusses over the same extent, and thereby greatly increases the angle formed at the center by the stiffening trusses and cables of one half-span with those of the other half-span.

Our principal aim in the calculation of stresses due to the drop of cables in the center was to find the maximum secondary stresses of the cables, and the tension in the center suspenders due to this cause. We therefore found the total drop due to high temperature and full moving load.

We then used the results, also, to find whether or not the stiffening trusses between ends of stay system are overstrained. We mentioned that our stresses due to the greatest drop of cables at center of main span, do not occur at the same time with maximum moving load stresses in stiffening trusses; and if the result had been that they combined with the maximum stresses from the moving load, are excessive, a more accurate calculation would have been necessary to find whether the stiffening trusses are safe.

We calculated the largest angle formed by the cables at the center of the main span both with the assumption of points of contraflexure 300 ft. from center of main span, and with those points at ends of stay system. We used the latter results so as not to exaggerate the secondary stresses in cables, which would be larger if the points were taken 300 ft. from center of span. The stiffening trusses were also calculated by assuming the moments zero at ends of the stay system. This gives larger stresses than would be obtained with points of contraflexure 300 ft. from the center of the main span.

We believe our stresses in stiffening trusses are not smaller, but as we state, rather larger than the actual ones if our assumptions in regard to the adjustment of the bridge are correct. If these assumptions are not correct, the adjustment could be changed to agree with the assumptions. We did not find any unavoidable excessive stresses or any indication of weakness in the stiffening trusses between ends of stay system. It is true we did not calculate the wind stresses, but these occur only in outside trusses, to which alone the lateral ropes are connected; and in these the stresses per square inch due to moving loads and changes of temperature are only about half as large as in the intermediate trusses, which are twice as high.

We observed the slotted holes in the top chord splices at the points mentioned by our critic, but the condition of the paint indicated that there had not been the slightest motion at them since the previous painting. The stresses are therefore probably small at those places, and the slots are unnecessary.

The removal of cable wrapping at the center of the span, and its replacing by a steel shell, will make any local bending at that point harmless as long as the radius of the curvature produced is large enough not to produce excessive inequality of stress in the cross-section of the individual wires. A cast-steel sleeve extending over the distance between the two center suspenders would also remove the secondary stresses of the cables due to the imperfect action of slip joint. If the ends of the cast-steel sleeves are properly designed, a too sharp curvature of wires will be impossible.

We believe steel shells and their connection with the sleeves and wire wrapping can be made much more watertight than the wire wrapping itself. Condensation and capillarity need not be feared any more with a shell than with wrapping.

It is suggested that the removal of suspenders near the towers will increase the bending stresses in cables at the center of span. This is true as long as the cables are wrapped at that place, but with the wrapping removed large bending stresses become impossible. We propose to put more load on stays for the purpose of relieving the cables and enabling them to carry increased moving and dead load without increase of stress. The suspenders near the towers become thereby superfluous; we therefore proposed to remove them. If not removed, some would have to be replaced by longer ones, the others would have to be shifted to points at cables farther from the towers, and their length readjusted to their new position. All these changes would cause a great amount of nearly useless labor.

Vibration of stays can be prevented by small wire ropes leading from the floor and nearly perpendicular to the stays.

We found by calculation, subsequent to the publication of our report, that the change in distribution of load among cables and stays by change of temperature is small for the part of the stay system near the towers. It only becomes large for the part near ends of the stay system. Temperature stresses would therefore not justify either the removal of suspenders near the towers or the introduction of complicated details to secure a constant distribution of stress between them and stays at different temperatures.

The bridge would be abundantly stiff over the whole extent of stay system without suspenders as far as stays extend, as can easily be shown by calculation.

Referring to stresses in cables due to different temperature of different parts of cross-section of cables, it is evident that such stresses exist and that they amount to about 200 lbs. per sq. in. for every degree Fahrenheit of difference of temperature of the part considered in comparison with the average temperature of the whole cross-section of the cable. We believe that on account of the shielding of the longitudinal wires from the direct rays of the sun by the wrapping, and on account of the fact that the wires are good conductors of heat no wire of the cable will be more than 10° colder than the average temperature of all the wires at the cross-section considered. If this is so the secondary stresses due to this cause will not exceed 2,000 lbs. per square inch. If, instead of the wrapping, a steel shell is used for cable cover with a bad conductor of heat or merely air between the shell and the longitudinal wires, at those parts of the cables where the secondary stresses from other causes are considerable, then the harmful effect of the secondary stresses due to the different temperature in different parts of the same cross-section of the cables becomes trifling. It is therefore unnecessary to make any change in the cable cover on other parts of the cables.

The ultimate strength of cable wire used in the report, 160,000 lbs. per square inch, was the minimum strength allowed under the printed specification which governed the manufacture. W. A. Roebling states, Jan. 9, 1882, p. 6, that "the average strength of the cable wire was 170,000 lbs. per square inch." It seemed to us, however, that, especially as the stresses throughout a cable are not uniform, only the minimum strength of the wire should be used for judging the ultimate strength of the cables. The latter would also be somewhat reduced by the splicing of wires. While Colonel Roebling says "the method of splicing the wires was such that the full strength of the wire was maintained at all the joints," we think it very doubtful if splices giving the full strength of the wire are practicable even at the present time.

It is possible that a more complete investigation of the bridge, especially of the approach spans and lateral system, which we did not find time to look into, may reveal inadequacy of the stiffening trusses. A survey of the bridge and much more complete calculations than we have made would be required to prove conclusively that the stiffening trusses are adequate or can be easily made so. Outside of the stay system they are in good condition and have shown no weakness. We condemn in our report only those parts which we can prove to be inadequate; we did not necessarily intend to approve all those which we did not condemn, as is evident from our statement that other changes than those which we recommended may be necessary to make the bridge entirely safe. Nothing we have so far discovered would, however, justify the replacing of the present stiffening trusses by entirely new ones.

Mr. Lindenthal apparently believes that the whole superstructure, with the exception of cables and stays, ought to be discarded and replaced by a new one. His aims are reduced dead weight, greater rigidity, vertically and horizontally, greater transportation capacity, increased margin of safety, and not much interference with traffic.

We believe the first is only to a small extent attainable, and of no importance as an aim; his last aim we believe to be of the very greatest importance and unattainable by his methods. We think the bridge rigid enough vertically and horizontally, and agree with him in regard to the increased transportation capacity and increased margin of safety.

In regard to the necessary rigidity, the possible variations of opinion have now been exhausted. Mr. Morison proposes 10 ft. deep stiffening trusses without stay system; Mr. Lindenthal thinks 17 ft. deep stiffening trusses with a stay system are too flexible, and we maintain that the present bridge is rigid enough. Its horizontal motion is very small and its vertical motion, though considerable, has never interfered in any way with traffic or alarmed the public.

The extreme difference of opinion on this point is due to the fact that the permissible amount of motion in a suspension bridge is partially governed by the consideration that it must not alarm the public. This amount cannot therefore be calculated.

We believe that even a stiffening truss only 10 ft. deep, that is not overstrained, will not allow a dangerous amount of vertical motion. It may, however, cause excessive grades or alarm the public. The former can be calculated, but the latter is a matter of observation only, which is impossible, before the construction of the bridge, and parallel cases may not exist.

Our opinion in regard to the adequate rigidity of present bridge is therefore based partly on the fact that no complaints are heard on this account.

On other points argument based on calculations should lead to agreement among unprejudiced engineers. It is believed that the disagreement in regard to the question of retaining or discarding the present stiffening trusses would disappear if the stresses in the same and their actual condition were more generally known.

We think it impracticable to replace the stiffening trusses in center half of main span by new ones, without serious and long continued interference with the traffic. This ought, therefore, not to be undertaken before the present stiffening trusses have been shown to be beyond repair.

Joseph Mayer,
Edwin Duryea, Jr.

No. 1 Broadway, New York, Oct. 30, 1901.

Notes and Queries.

In the article on the new sewage disposal plant at Madison, Wis., published in our issue of Oct. 17, the capacity of the intermediate tank between the septic tank and filters should have been given as 500 cu. ft., or 3,740 gallons, instead of 500 gallons. A correction to this effect was sent to us by Professor Turneaure, but it did not arrive until the article was in print.

CAN PRESENT STANDARD ROAD SPECIFICATIONS BE IMPROVED?

By Halbert Powers Gillette.*

It is my purpose to call particular attention to certain clauses in the "standard specifications" for macadam road-work as exemplified in present practice in the states of New York and Massachusetts. Since the New York specifications have been largely copied from those of Massachusetts, and as they in turn have been compiled from English, French and German sources, we may expect to find specified an amount of "sandpapering" and unnecessary labor that is characteristic of foreign engineering work. The clauses that will now be quoted and criticised are from the specifications for recent New York State road work; but equally indefensible clauses are to be found in those of Massachusetts.

The first paragraph is as follows:

KIND AND SIZES OF BROKEN STONE.

The broken stone shall be of two courses. The bottom course will be 4 ins. thick and may consist of trap rock, granite or any of the harder grades of limestone not inferior to the specimen exhibited in the offices of the State Engineer and Surveyor and of the Engineer of the Western Division, which stone shall be broken in sizes varying from a minimum of 1½ ins. to a maximum of 3 ins. in their longest dimensions.

The top course shall be 2 ins. thick after rolling, and shall consist of trap rock broken in sizes varying from a minimum of 1 in. to a maximum of 2 ins. in their longest dimensions.

Limestone screenings not exceeding ½-in. in size and free from all dirt shall be added to fill all interstices that cannot be filled by the rolling or compacting if the other stone. Such screenings must be free from earth, sand, loam or vegetable matter and shall contain all the dust of fracture.

Apparently this is not so unreasonable a specification until examined very carefully, which (to their sorrow), many contractors have not done. It will then be discovered that no provision is made for the use of the ½ to 1½-in.-sized product of local stone in the lower course. That is to say, all the local stone, limestone for example, from ½ to 1½ ins. in size, is rejected by the State and so rendered worthless—unless the contractor is fortunate enough to find a market for it, which is impossible where the haul is at all long. This size of stone forms about 25% of the crusher output, and its rejection, therefore, means an added cost of 33% per cu. yd. of product that can be used. Thus: If the total product of the crusher costs $1 per cu. yd., and only three-fourths of this product can be used, that three-fourths must bear the whole burden of cost, and becomes worth $1.33 per cu. yd.

The taxpayers must in the end pay for such waste, and that it is entirely unjustifiable can be proven by the existence of good roads where every particle of stone coming from the crusher has been used. This clause unquestionably came into existence through blind copying of the Massachusetts specifications, where both upper and lower courses were of trap, and therefore not subject to the same criticism. Even after attention had been called to the error, the New York specification remained unchanged, the reason given being that large stone are preferable anyway for the lower course, and the contractor should find some other use for the smaller product. This reason was not only an afterthought, but entirely erroneous; for were it not for the greater cost of crushing stone fine, smaller stone would usually be preferable in the lower course, as they are less easily driven into the subgrade by rolling.

Secondly, note in the above specification that the binder for both courses must be limestone. On the Ridge Road, near Rochester, for example, the lower course was sandstone, so that the limestone binder had to be imported from the Hudson River by canal, and from Le Roy and Buffalo by rail. Thus, according to the specification, not only the sandstone, ½ to 1½ ins. diameter, was a waste product, but also the sandstone screenings. In order to save himself from another source of loss that will presently be pointed out, the contractor used some of the fine product underneath the "lower course," and by judicious handling of his coarse product he was enabled to so roll it as to force it down into the fine (and otherwise waste) product, thus partly filling the voids of the coarse stone, and saving limestone screenings.

Now, why were the sandstone screenings rejected in the specification? Presumably because it was reasoned that quartz-like screenings would not bind. Sandstone has, however, been used in many roads as a binder, and where slow in binding the addition of a little dust, preferably limestone, quickly accomplishes the desired end.

It will be observed that trap-rock screenings are rejected. Since trap is not a local product, but is shipped from the Palisades by boat or rail, it might seem at first sight that the State incurs no loss in specifying limestone screenings for a binder, as Tompkins Cove screenings certainly bind more quickly and cost but little more than trap. But let us look a little farther: If trap screenings are uniformly rejected, the price of the coarse trap must ultimately be raised for the very same reason as above given regarding the waste of the middle-sized local stone. Trap screenings, on account of the small amount of dust they contain, bind very slowly, and not until enough dust has been produced by the grinding of the coarse stone under the roller; this grinding, however, wears the coarse stone round, and is, therefore, objectionable. To cause trap screenings to bind quickly, simply add a little dust, preferably road sweepings or limestone. All difficulty from using trap screenings will then vanish, and their use will cheapen road construction.

Another feature of the clause under discussion is the size of trap specified. I have been unable to find any trap quarryman on the Hudson who uses screens that produce stone "not less than 1 in. and not more than 2 ins. in diameter." To produce such stone new screens would be required at great cost. However, this difficulty has been overcome by paying no attention at all to the specification, it being practically impossible for an inspector to ascertain the size of screens used when they are several hundred miles away. Incidentally I would say that the commercial size of crushed stone, as "1½-in. stone," means that its average diameter is about 1½ ins., and not that its greatest diameter is 1½ ins.; thus, "1½-in. stone" is stone that will not pass through a 1 1-16-in. hole, but will through a 2¼-in. hole. The size actually used by most contractors under the above specification has been the "2½-in. stone," ranging from 2¼ to 3¼ ins. in diameter, and its use has proved very satisfactory.

A letter to any of the trap quarrymen will secure information that will prevent the specification of sizes not made.

THICKNESS AND WIDTH OF PAVEMENT.

Passing now to the standard width and thickness of the macadam on New York State roads, we find it to be 6 ins. by 16 ft., with occasionally a 12-ft. road. Upon very soft sand or clay subsoil it is necessary to have about 6 ins. of pavement or more, but upon ordinary soils which are loamy or gravelly 4 ins. will suffice, and should, therefore, be made the standard thickness if there is to be a so-called standard. The main function of a pavement is not to shed water, as commonly stated, but to distribute a concentrated wheel load upon a sufficiently large area of subsoil that will not yield under the pressure. Incidentally, the drier the soil (sand excepted), the more resistance it gives to pressure, whence it is desirable to provide a pavement that will keep the subsoil dry; but this is a secondary though important consideration.

A thick pavement is necessary upon sand and on clay, when the latter is not well drained; but thickness should not always be obtained by the use of expensive broken stone, but by gravel where available at less cost. Thus, on clay or sand, 3 to 6 ins. of gravel should ordinarily form the lower course upon which 3 or 4 ins. of macadam for a wearing coat should be laid, instead

*791 Powers Block, Rochester, N. Y.

of invariably using 6 ins. of macadam, as is now done in New York and Massachusetts.

A street built in Rochester 25 years ago has 9 ins. of macadam upon a 12-in. telford foundation. It admirably typifies English practice, which to a less extreme we still see in our "standard road specifications." To build a 4-in. macadam road, and afterward thicken it in places, if experience with the soil proves necessary, is not "cheap and nasty" construction, but truly economic engineering.

Next let us consider the 16-ft. width ordinarily specified. This is, I think, a concession to residents along a road who usually raise a great outcry when a pavement of less width is proposed. Indeed, 16 ft. seldom satisfies their desire for greater width until after the road has been built.

As has been aptly remarked, what farmers most need is not width, but length, in their paved roads, and any expedient that will decrease the standard width must necessarily add to the mileage built. Where townships own their own crushers I have observed that they seldom pave wider than 7 or 8 ft., and the roads so built are not objectionable on account of the narrowness so much as on account of the crude manner of building. I am well aware that a narrow roadway causes a concentration of wear, and frequently rutting of the macadam; and in consequence we find roads wider than 12 ft. advocated by the Massachusetts Road Commission. But I would call attention to one point, namely, that no data have ever been published showing the actual loss of material over the total road surface of a narrow road as compared with a wide one.

For several reasons I incline to the opinion that a narrow (8-ft.) road would compare very favorably with a wide (16-ft.) road. Traffic follows the center of a 16-ft. road in any case, and the wear is almost as much concentrated as upon a narrower road. Weathering causes considerable loss of material, and this loss must be twice as great on a 16-ft. road as upon one 8 ft. wide. Let it even be granted that an 8-ft. road would rut quicker, it simply means that the intervals of resurfacing by a steam roller, as described in Engineering News of June 6, 1901, will be somewhat shortened at but little added cost.

Therefore, without actual data to prove their contention, the engineers who advocate wider roads solely to save in maintenance, have very feeble arguments for their support.

A more serious objection to an 8-ft. road is that two teams can not pass on it; but there is a very simple and a very satisfactory way out of this difficulty where the road is not built for a speedway but for the hauling of farm produce. Turnouts, where the width of pavement is 16 ft. for a length of 40 ft., can be provided 320 ft. c. to c., requiring only as much material as would add 1 ft. to the width of the road for its whole length. I have built plank roads 8 ft. wide where the turnouts were much farther apart, and after they were once built complaint as to narrowness entirely ceased. A macadam pavement 4 ins. by 9 ft. requires less than 600 cu. yds. of stone per mile, which, at $3, would make the cost of paving only $1,800 a mile for an 8-ft. road, with turnouts as described.

If, after it is finished and has been used for a time, a narrow 8-ft. pavement does not satisfy those using it, it can be widened usually at less cost than if built the full width in the first place, for the material for the widened portion can be hauled much more cheaply over the macadam already built than it could be over an earth road. Thus is removed the only possible objection to experimenting with a narrow road in a district where by chance a wider one may be ultimately required.

If, however, the residents desire and can afford a wide road upon which teams may be driven without stopping at high speed in opposite directions, a 16-ft. road must be provided. Where the local stone is of such quality that a surface coat of trap 2 ins. thick seems desirable, it is unnecessary to cover the local stone to its full width with trap, especially when the local stone is of fair quality itself. I have built a 16-ft. macadam road of the cross-section shown in Fig. 1, the trap being only 12 ft. wide, but it would have been cheaper and quite as durable to have made the trap only 8 ft. wide, as in Fig. 2. As a matter of fact, since it is the wheels that cause the greatest wear by rutting, there is good reason to believe that Fig. 3 shows an equally good and even more

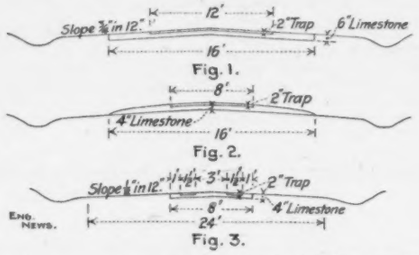


Fig. 1.

Fig. 2.

Fig. 3.

Designs to Economize Trap Rock Wearing Course in Macadam Roads.

economic design, provided the local stone is a good quality of limestone or the like that will not wear so much faster than the trap as to leave the trap in a ridge.

MEASUREMENT OF STONE.

The next clause in the specification that we shall consider is the following:

DEPTH OF PAVEMENT.

The pavement, when completed, shall be at least 6 ins. in depth, irrespective of the surfacing material, as is required by the specifications, and of such crown and form of gutter as are shown on plans; and in any case the thickness of the pavement is to be determined on a line at right angles to the grade and crown.

NO ALLOWANCE WILL BE MADE FOR ANY MATERIAL DRIVEN INTO THE SUBGRADE BY ROLLING OR MISTAKE MADE BY CONTRACTOR IN EXCAVATING OR FILLING. The use of a proper roller, rammers or other suitable implement is to be substituted for that of the steam roller when the engineer so directs.

Here we see, what is not uncommon, an effort to throw all the uncertainty of cost upon the contractor. The contractor must guess whether there will be 1 in. or 4 ins. of stone driven into the subgrade, and if his guess is not correct, he must lose or gain as the case may be. He usually loses if not a man of long experience. Such specifications are not only morally but economically wrong. The inexperienced contractor is almost certain to lose a just compensation for the work that the State is able and willing to pay, while the experienced contractor will err if at all on the side of safety, and so receive pay for material that he will not have to furnish.

This specification is, moreover, based upon a false reason, for it implies that all stone driven into subgrade is lost and valueless, which is not the case. When stone is driven down, the soil is forced up into the voids, and there results a macadam with a binder of sand or loam which, if not as good as macadam bound with screenings, is nevertheless capable of aiding in the distribution of a concentrated wheel load, and therefore performs the most important function of a pavement. It is desirable, of course, to drive as little stone into subgrade as possible, which end can be attained in any of several ways that need not be discussed here.

The only fair way to pay for macadam in thin roads is either by the ton or by the cubic yard in the wagons. No effort should be made to finish a road surface exactly to a predetermined grade, as is the present practice in Massachusetts and New York.

FINAL SURFACING.

Before passing from the subject of macadam, another short clause will be considered:

After the wave has been produced over the whole section of the road, screenings shall be again spread on where required to leave them ¾-in. deep for a wearing surface.

To cover a 16-ft. road to a depth of ⅜-in. for a mile requires about 100 cu. yds. of screenings, which, when imported by rail and hauled, seldom cost less than $2 a cu. yd., and frequently $3. Thus, to provide a perfectly useless "wearing surface" we find the State expending some $200 or $300 a mile. Any screenings over and above those needed to fill voids serve no useful function upon a road, except to prevent horses' hoofs from loosening the stones, and to keep the macadam from ravelling, for which purpose sand or loam serves equally well.

MATERIAL FOR EMBANKMENT.

We pass now to a clause relative to earthwork:

Embankments shall be formed of clear earth or other materials satisfactory to the engineer, and shall be free from vegetable matter or refuse of any kind.

Under this specification the Division Engineer of the Western Division states on p. 556 of the last annual New York State Engineers' Report that 2,000 cu. yds. of soil containing sod are removed and wasted per mile of road, which means a waste of about $500 per mile; and I say waste advisedly. The roots of grass extend the full depth of a plow furrow, and as, according to the specification, the grass and its roots must be entirely removed, it can only be done by taking with them the earth to a depth of 6 or 8 ins. While sod may not be desirable in a very shallow embankment covered by macadam, it may to advantage be used to form the shoulders at the sides. An economic and efficient method of separating the green grass and weeds from their roots is by use of a mattock, thus taking off about 1½ ins. of soil, instead of 6 to 8 ins. The roots, which are an insignificant fibrous portion of the soil, may then be allowed to form part of any embankment. This results in saving thousands of yards of otherwise wasted earthwork, and the cost of separating the sod from the soil is only ¾-ct. per sq. yd. of surface so treated, labor being 15 cts. an hour. I have treated elsewhere the subject of the most economic transverse profile of the earth subgrade, and shall only touch upon it here by repeating that the ditches (2 and 3 ft. deep), shown in standard designs, are altogether deeper than necessary, and, therefore, are wasteful of earthwork.

Summing up, we conclude that the cost of paved roads may be reduced so as to place them within the reach of every settled section of New York State by the following changes in present standard designs and specifications:

(1) Change specifications so as to permit use of every particle of stone coming from the crusher.

(2) Change specifications so as to permit use of trap screenings for trap rock, and sandstone screenings for sandstone; specifying limestone screenings, if at all, only in quantity sufficient to furnish a little dust to facilitate binding with other screenings; and provide no "wearing surface" of screenings.

(3) Change designs, so as to make the standard thickness of macadam about 4 instead of 6 ins.; and the standard width 8 ft. with turnouts instead of a uniform width of 16 ft.

(4) Change design, so as to provide gravel or the like for the lower course of the pavement where it is necessary to have a thickness of pavement greater than 4 ins.

(5) Change design so as to use trap when used at all for a width of only 8 ft. in the center of a road where the road is 16 ft. wide, and local stone is of fair quality.

(6) Change specifications so as to pay for stone by the ton, but in doing this do not regard stone driven into subgrade as lost, for it is still valuable; in other words, do not grade to a predetermined level and then fill in with stone until the finished surface reaches another predetermined elevation.

(7) Change specifications so as not to exclude grass roots, and thus save $400 a mile now lost in wasting all earth containing vegetable matter.

(8) Change transverse profile so as to reduce depth of ditches, and so save earthwork.

By following these suggestions it will be possible to reduce the cost of New York State roads from the present $8,000 or $10,000 per mile to even less than the $4,000 per mile of New Jersey roads. It is perfectly feasible to build good, serviceable macadam roads in New York State for about $3,500 a mile. They will not be speedways upon which teams can pass at a full trot, but they will be hard, unyielding surfaces over which great loads may be drawn in all kinds of weather, which I take it is what the farmers want.

(In view of the direct criticisms in the above article of the specifications in use by the New York State Engineer's Department, and by the Massachusetts Highway Commission, we submitted a proof of this paper to each of these offices with invitation to make reply, if they chose, in the same

We have received the reply printed below from the State Engineer's office.—Ed.)

article contributed to Engineering News, entitled Present Standard Specifications Be Improved," shows thought on the part of the writer, and contains ections and criticisms which would be more valuable were based upon New York road specifications could in any sense be called "present." The ections which are criticised are largely those which in use in 1899, but have since been modified in ways.

any roads now building the sizes of crushed stone arranged as to use the total product of the crusher, ding screenings, which are used to form the binder filler. There is now none of the "waste product" hich the writer complains.

cases where the screenings of granitic rock do not well an admixture of limestone screenings is made ecure this result. In some cases local sand is used this purpose. In all cases full use is made of such materials as will produce the hard roads desired, every means are used which will give good results at least cost.

In a recent communication to the Engineering News from the same writer the State Engineer of New York was criticised for refusing to use sandstone in road construction. In this case, also, the writer was under a misapprehension, for three roads are now in process of construction by State aid in which local sandstone (or "bluestone") form not only the base and the top, but also the filler or binder; while a similar road, five miles long, was built of this sandstone during 1900, and is described and illustrated in the annual report of the State Engineer, published in January, 1901.

TENDERS FOR DRAINAGE WORK in the Province of Buenos Aires, Argentine Republic, are invited by the Commissioners of Drainage Work for that province. Over 620 miles of main drainage canals and branches will be required in certain regions subject to inundation. All information as to the proposed work can be obtained by addressing the Secretary of the Argentine Legation at Washington, D. C., or 16 Kensington Palace-Gardens, London.

THE PRICE OF CALCIUM CARBIDE has been considerably reduced, according to an announcement by the Union Carbide Co., which controls the manufacture and sale of carbide in the United States. The new prices are $3.75 per 100 lbs. in less than ton lots, or $70 per ton for ton lots at all distributing points east of the Missouri River and north of Charleston, S. C. This reduction in price will have an important influence in assisting acetylene lighting to compete with other systems.

MUNICIPAL TAR MACADAM AND CREOSOTED wood block paving plants for Duluth, Minn., are said to be under consideration. The city has quarries from which stone for macadam is obtained and tar is available at the municipal gas plant. It is urged that the abundance of tamarack at Duluth is favorable to the production of creosoted wood paving blocks.

A 200,000-BARREL OIL WELL AT BEAUMONT, Tex., has been struck by the Texas Oil & Pipe Line Co. For the first time, it is said, an 8-in. pipe was successfully sunk to the oil sand, instead of the usual, 2, 4 or 6-in. pipe. With an 8-in. pipe, clogging by sand is made impossible, and the output of the well proves the wisdom of the company named in expending the time and money necessary. The pressure caused the oil to spout an 8-in. stream 300 ft. high, says a Beaumont correspondent of the New York "Tribune."

THE REFRIGERATOR PLANTS for the two great Pacific steamers under construction at New London for the Great Northern Railway Line, are of the ammonia-compression type, electrically operated. Each plant will have a daily capacity of 120 tons, and the evaporating plant a daily capacity of 80 tons of fresh water.

THE LIVERPOOL ELECTRIC TRAMWAY SYSTEM now comprises 100 miles of track, operated by 350 cars, and these carry over 2,000,000 passengers per week. For 75,000,000 passengers carried in the first nine months of this year the traffic returns amounted to $1,750,000, and for the same period the gross profit amounted to $575,000, or a net profit of $200,000 after providing for interest and sinking fund and for maintenance.

THE LINING OF THE MUSCONETCONG TUNNEL WITHOUT INTERRUPTING TRAFFIC.*

By Willard Beahan, M. Am. Soc. C. E.†

It became necessary in 1899 to line a portion of the Musconetcong Tunnel on account of heavy falls of rock from the roof. This tunnel is on the Lehigh Valley Railroad in the State of New Jersey, and 65 miles from New York city. It is 4,829 ft. long, and is built for two tracks. The alinement is a tangent and the grade descends each way from a level in the center of the tunnel (Fig. 1). The portals are each at the head of a valley, the west portal being in a sharp crook in that valley. This crook shuts out the west wind and makes it the weaker air current and the east wind by far the stronger for tunnel ventilation, the importance of which fact will be seen later.

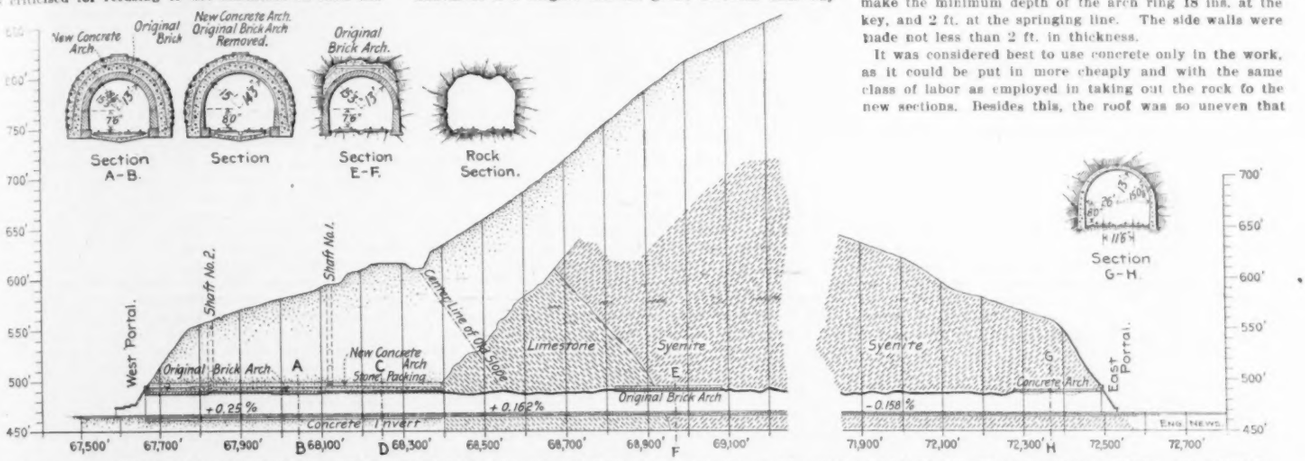


FIG. 1. LONGITUDINAL AND TRANSVERSE SECTIONS OF MUSCONETCONG TUNNEL, SHOWING ARRANGEMENT AND CHARACTER OF LINING.

The Musconetcong Tunnel was driven in 1872-5. At the west end it was lined from the portal in for several hundred feet. Brick was used for the barrel of the tunnel, but the portal was of stone masonry. The old masonry lining has given some trouble and was largely rebuilt in 1888-90. The brick used, the writer understands, had not lasted well and part of the backing was found to be somewhat faulty. From where the roof near the west end became sound and strong, until the tunnel reached to within 5 ft. of the east portal, there was never any lining used prior to 1899. The east 15 ft. of the tunnel was lined with stone masonry. This masonry was uniform in kind with the portal masonry itself. The roof of the tunnel is a gray granite with seams, and the overlying material is a gravelly loam with some clay. The tendency is towards a wet roof. There is always some water flowing out of each portal—principally from points not far in the tunnel from the portals. While the rock is fairly good roof, it needs inspection and some rock removed every 30 days, from November until May. Such has been the practice for years.

Owing to a change in some of the officials and a lack of insistence on the part of those remaining, as well as some misconstruing of orders, the roof of the Musconetcong Tunnel was not inspected or any loose rock removed for a period of nearly a year. In March, 1899, a mass one-half as large as a car body fell from the roof at a point 160 ft. in from the east portal. It appears that there was not much reliable roof of rock remaining at that point. The earth roof was some 50 ft. deep. The situation was so threatening that lining this part of the tunnel, beginning at the end of the stone masonry lining 15 ft. in from the portal, and extending for a distance of 240 ft., was at once recommended by Mr. W. O. Sprigg, then Superintendent of that Division, and by Mr. W. G. Berg, then Engineer of Maintenance of Way. The intention was to commence the work as soon as the flow of water subsided after the spring rains, as the traffic in the spring months was lighter than in the fall. The prevailing wind in the spring and early summer was a strong and unobstructed wind from the east. This would carry the smoke of passing engines into this tunnel and quickly drive it west of the east portal where the lining was to be placed. The estimated cost was based on this plan and was placed by Mr. Berg and myself at $50 per lin. ft. For some reason, no doubt fully sufficient, the work was not authorized until July 26, and it was started Aug. 1.

The first question to be decided was the section to which the intrados of the lining must conform. Since the adoption of the section used at the east portal, where the tunnel was lined for 15 ft. with stone masonry, would involve enlarging the average rock section as much as economy would ever demand, Mr. Berg decided to continue the east portal section in for 240 ft. It was decided to make the minimum depth of the arch ring 18 ins. at the key, and 2 ft. at the springing line. The side walls were made not less than 2 ft. in thickness.

It was considered best to use concrete only in the work, as it could be put in more cheaply and with the same class of labor as employed in taking out the rock for the new sections. Besides this, the roof was so uneven that rock or brick could not have been used. The arch ring was 11 ft. thick at one point.

The next problem to be met was to plan the work to disturb the traffic as little as possible. It was thought that during the hours the men were at work two tracks could not be used, and it was proposed to abandon the west-bound track entirely, as that track had, of course, the least tonnage. It was also proposed to put the east-bound track on the center line of the tunnel so as to give working room on each side of the single traffic track. But since it was then August and the fall traffic was approaching, and would surely be heavy, the trainmaster was very urgent that he be given two tracks a part of the time, and have two tracks that could be used to raise or prevent a freight blockade. For this reason, and to enable the trainmaster to have two tracks at all times when the work on lining was not going on and at such other times as possible a gauntlet track was devised.

The general design of this track is shown in Fig. 2. It is essentially a single track for operating purposes for about 1,000 ft., but it is so arranged that it can be converted into two tracks or back again into one track in two minutes' time. Split switches were used. We ran on one side of the inner two of the four track rails when the switches were in one position, and on the other side of those two rails when the switches were in another position. In other words, alternate sides of these rails were the flange sides. To do this we were obliged to remove the splices, as shown, throw the rail into the new position and put on the splices again, so as to connect with the rail to be then used. This gauntlet track we believe to be novel and it was perfectly satisfactory. The gauntlet track gave working space on each side of the traffic. A rail used with the two outside rails and 2 ft. from them made a tram track on which small cars were used. They were pushed by hand and carried out the muck. A plank was spiked on the ends of the ties as a runway for wheelbarrows, which were sometimes used in wheeling out muck and always for wheeling in the concrete.

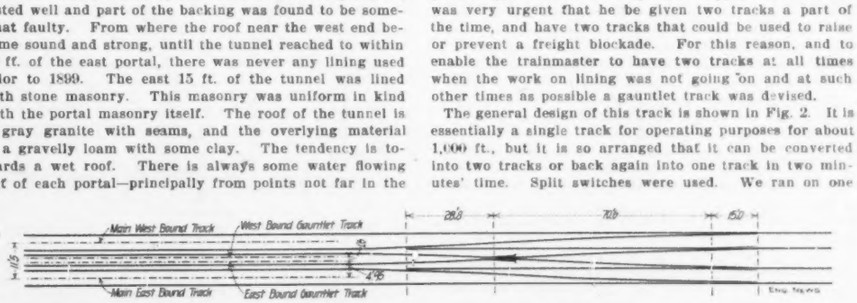


FIG. 2. PLAN OF GAUNTLET TRACKS USED IN RELINING MUSCONETCONG TUNNEL.

*Abstracted from a paper in the "Transactions of the Association of Civil Engineers of Cornell University for 1901."

†Division Engineer, Chicago & Northwestern Ry., Minn. & Dak. Division, Winona, Minn.

The concrete platform was located along the east-bound track near the tunnel. It was at safe clearance distance from the track for coaches and at the height of a car-floor above the main track. It was wide enough to meet the slope of the cut, and on the back slope a considerable supply of crushed stone and sand could be kept. The cement house stood at the end of the mixing platform.

Trains through the tunnel were handled from the tower at the east portal. Experience showed that it was also necessary that this towerman should have control of the gauntlet track. Therefore a telephone was put in the cement house and the foreman in charge of the work communicated with the towerman before changing double track to gauntlet track and vice versa.

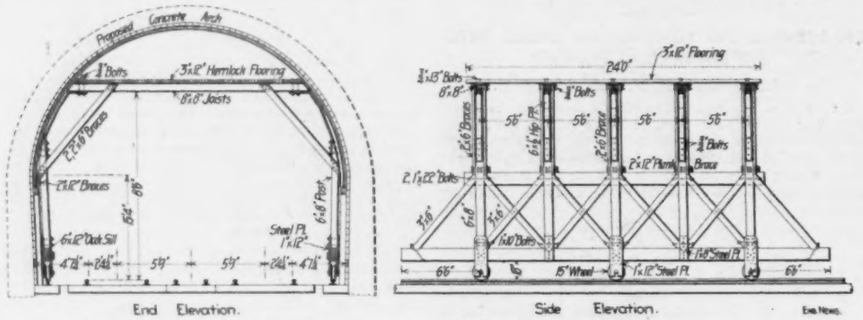


FIG. 3. DETAILS OF TRAVELER USED IN LINING MUSCONETCONG TUNNEL.

The method of attack for the work made space and clearance the difficult question, and we had trouble to get room enough on the side for supports and head room on top for the men. The two tracks were shifted 6 ins. towards each other since that could be done and the cars have as much clearance between tracks as they had on the outside at certain points in the tunnel. A rail to carry a traveler was laid on blocks fastened by cleats to the outer end of the ties and as far from the center line of the tunnel as necessary to give free clearance. A traveler was built as shown in Fig. 3. The wheels were double flanged, and the timbers hard pine. The only iron members were the hip irons which were first made ½-in. thick. But the wooden braces took time to put on and take off when the gauntlet was changed, so new hip irons were made 1 in. thick and the braces not used. This was the only change made in the traveler or centering. The cross beam resting on the hip irons and carrying the planking for the working platform was so low that there was but 2 ins. clearance under it for the highest members of the rolling stock. The traveler was erected just outside the portal and rolled in on its rails to the east end of the portion to be lined.

The drilling was done by hand and it required good men, for the holes were in all directions. Usually two hammers were used on each drill and four drills kept going in the roof by preference. The cutting was not very heavy on the sides which were blasted out ahead of the traveler, ladders being used or horses and planks for platforms. As a rule 40% dynamite was used but we had some 60% dynamite and some black powder on the work. The 60% was too strong and shook the roof outside the desired section while the last was too weak for granite in our shallow holes, which were fired with caps and a battery. In heavy roof shots, the traveler was run back and ties placed under the shot to protect the track. Usually the tracks could be cleared of muck after a shot in ten minutes, but in some cases 20 minutes were required. The traffic, however, was not delayed, only the frick dispatcher knowing of us or the work. No complaint ever reached the chief dispatcher or the trainmaster, and the merit for this work lies in this fact.

The centering was crowded for room, although the main tracks were shifted 6 ins. closer together, and the posts of the traveler were placed close to the cars. Even then there was barely room for any support for the arch ribs or side wall lining. The plan of the centering, and the detail of the arch-ribs are shown in Fig. 4. The temporary side posts were set up first, lagged up for a few feet from the tunnel floor and filled with concrete. When both sides were filled to the springing line and the concrete had set, these temporary posts were removed and the thinner posts which carried the plates on which the arch ribs were to rest, were then set in place. The arch ribs and all iron work for the centering were made by the Cockburn Machine Co., of Jersey City. The ribs fitted the semicircle of the intrados, leaving room for a 2-in. lagging, and they were bolted and spliced together at the key—each rib being in halves. The foot shoe of the rib on each side rested and fitted into a sand box of cast iron, in the side of which near the bottom was a hole closed with a screw bolt. In striking the centers the screw bolts were removed and the sand allowed to run out, or was scratched out, thus slacking off the rib. These sand boxes were suggested to me by Mr. C. C. Barr of the former firm of Anderson & Barr.

In setting up these ribs at first they were not straight and each one or each pair in whatever order put together was alike. Instead of being as though cut from a half cylinder by a plane at right angles to the axis of that cylinder, the ribs were helicoidal. Can any one explain that? It has occurred before. The ribs were strong and had not changed shape when the work was finished. A 10-ft. section in length was concreted at each time in the roof and about a 16-ft. section at one time on the sides. Concreting could not be rushed for fear of the lagging bulging out and putting traffic in danger as there was not room for all desired braces. By giving time for the hardening of the concrete no risk was incurred. As the concrete approached the key on each side for a section, stiff struts were put in at frequent intervals between the roof and the ribs, to keep the ribs from rising at the key, because of the heavy load on the haunches of the arch and no load as yet at the key.

There was placed in the concrete where the drip of water from the roof or flow from the side was heavy, a piece of iron pipe 3 ins. in diameter. This reached from the rock to the inner surface of the concrete. These drain pipes allowed the water to pass through and are imperative in tunnel lining.

The concrete was mixed by hand on the platform shown. It consisted of oolitic limestone crushed to pass through a 2½-in. ring and not pass through a ¼-in. square mesh screen. The sand was a sharp yellow sand not entirely free from loam. The cement was at first the Alpha Portland Cement Co.'s cement of Alpha, N. J., but that company not being able to then furnish it in the amounts required, the later and greater part of the cement used was Giant Portland from the Atlas Cement Co.'s works at Egypt, Pa. The proportions used were 1 of cement to 2 of sand to 4 of stone, all measured by bulk. The platform was water-tight. The cement and sand were placed together on the platform in a quantity for one batch. They were mixed together and then made wet with water. The stones were moistened and then placed on the mixed cement and sand. The batch was turned repeatedly with shovels and mixed so stiff that the water would just show through the mass after it was in place and rammed long and thoroughly. Wooden rammers were employed—the men standing on the walls and ramming them until above the springing line. Since a smooth inner surface was desired, the ramming was very carefully done next the lagging. It was not necessary to plaster the interior after completion although some of the crushed rock was quite large. No cement had laboratory test or inspection and the company foreman in charge of the lining and the repute of the cement were the safeguards.

The gauntlet track lay-out and detail was designed by Mr. W. M. Torrance, C.E., and he also designed the detail plans shown in Fig. 3. The details of all of the other work and the plans here shown were made by R. S. Palmer, C.E., draftsman of the work.

The work was done by a company force employed by the hour. All the work was done under the su... of Mr. T. P. Gaynor, foreman of work train on... part of the Lehigh Valley R. R. for 18 years. He pre... had experience in tunnel work for the company a... out all of the credit for the completion of the work w... acci-dent belongs to this foreman. He pronounced ... crucify-ing" work at the time. Alertness, cleverness, ... dulness, patience and good judgment were as much re... there in the entirety as on any work ever undertak... or for me. The wind was weak and in the wrong dire... The traffic was very heavy. Had the work been ... ed in April the strong east wind would have lessen... cost of lining at the east portal by 40%, as against ... weak west wind we dealt with. The gases from ... g en-gines did not leave the east portal as desired ... were slowly passed back by that portal from the w... This gas knocked out our men and when men have ... ed out two or three of their number the gang grows t...

Again, the traffic from April forward for a ... son is light on that line as compared with the traffic f... Aug-ust forward. A record kept for many years at ... tower at the east portal shows exactly what trains or engines pass through the tunnel. It is an official reco... faith-fully kept. The towerman submitted to me a written statement that for the 100 days which elapsed from the time we began until we completed work, there was an engine passed through the tunnel at an average interval of 10 minutes. We did not work nights or Sundays. Therefore, during our working hours an engine passed us more frequently than every 10 minutes.

It was a mistake to undertake to line that tunnel at the season of the year when it was known that the wind was most unfavorable in direction and strength. It was a mistake, but one of less moment, to undertake the work during the heavy autumn traffic. It was unfortunate for the tunnel work that the autumn of 1898 was the heaviest in the history of that road. The movement of the traffic affected the tunnel work but little, and troubled the trainmaster little if any more at that point than elsewhere. But a heavier tonnage meant more engines and therefore more gases at more frequent intervals.

The work was very unfortunate in one engineering respect—the cost exceeded the estimate. We solaced ourselves that it was a vernal estimate for what was an autumnal performance, but that gave but partial comfort. The estimated cost was $50 per lin. ft. of tunnel. The cost was $54 per lin. ft. of tunnel for all blasting, mucking, concreting and handling of material. This included all supplies and watching. But besides this there was a charge for temporary spur, platform, shanties, gauntlet track, train service, etc., of $29,91 per lin. ft. of tunnel lined, making a total cost of $83.91 per lin. ft. of tunnel lined.

The immediate superior of the writer at the time the work was being done was Mr. W. O. Sprigg, Superintendent of that division of the Lehigh Valley R. R. He did all in his power to aid the work. The plans and methods for doing the work were examined and approved by Mr. W. G. Berg, then Engineer of Maintenance of Way, now Chief Engineer of the Lehigh Valley R. R. Co., and under whose direction the work was prosecuted.

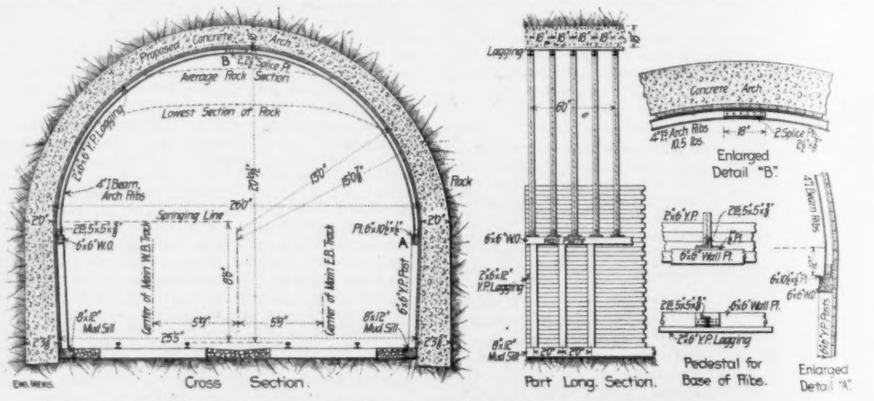


FIG. 4. DETAILS OF CENTERING USED IN LINING MUSCONETCONG TUNNEL.

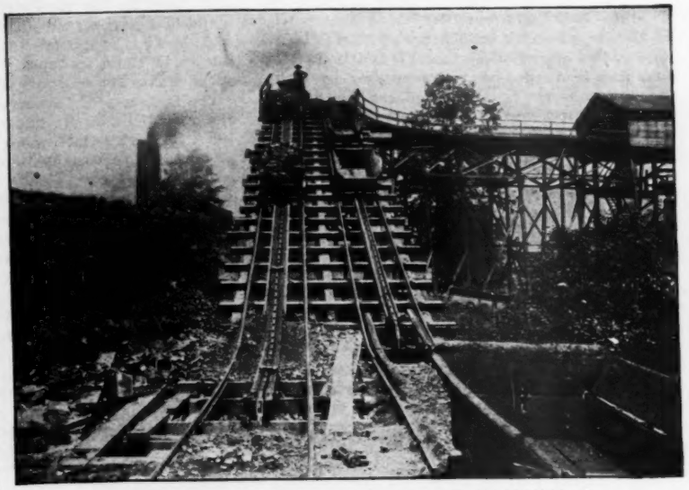
AN AUTOMATIC INCLINE FOR HOISTING MINE CARS.

We illustrate herewith an incline for elevating mine cars which was recently erected at Magnolia, O., for the National Fireproofing Co. The ascending track for the loaded cars is on the left-hand side, and the descending track is at the right. The usual automatic tipple for dumping the cars is at the top of the incline.

A heavy endless chain, as seen in the cut, passes up the ascending track and a somewhat lighter chain moves down the opposite track. Each ha...

spurs or car pull attachments at intervals by which the loaded cars are elevated on one chain and let down on the other.

The mine cars weigh 4,500 lbs. with their load and about three cars per minute are run from the mouth of the mine to the foot of the incline. The hoisting chain is of forged steel of extremely heavy construction, and travels at a speed of 60 ft. per minute. The car pull attachments are placed at intervals of 36 ft., and are carried on rollers. The chain on the down track is of steel bars 1½ × ⅜-in., with a 6-in. pitch. It is designed for a working load of 2,500 lbs., and runs at a speed of 100 ft. per minute. The car spur attachments are spaced 12 ft. c. to c. Each line of chain passes over sprocket wheels at the head and foot of the incline, and these wheels are connected through a train of gearing to the same driving shaft. Thus the power developed by the cars passing down the incline helps to hoist the loaded cars on the other track. The incline is 78 ft. in length between centers of head and foot shafts, and is inclined 22° to the horizontal. The whole machinery is driven by a ⅝-in. wire rope from a line shaft 250 ft. distant. To avert accident in case of slipping of the rope, breakage of gears or other failure in the transmitting mechanism, a ratchet wheel and pawl is provided on the head shaft.



AUTOMATIC INCLINE FOR MINE CARS AT MAGNOLIA, O.
Designed and Built by the Aultman Co., Canton, O.

The entire plant above described was designed and erected by the Aultman Co., of Canton, O., to whom we are indebted for the cut used in illustrating this article. The total cost of the Magnolia incline, including both the wooden construction and the machinery, was only $1,000, erected in place.

The same company have recently built an automatic incline on the same general lines at Meadowlands, Pa. Here the incline is 178 ft. long, and the angle is 20°. Loaded cars weighing 60,000 lbs. are hoisted at the rate of 70 ft. per minute, and the total capacity of the incline and coal tipple is 3,000 tons per day. A factor of safety of 10 is adopted for the chains used on this incline.

THE RECLAMATION AND IRRIGATION OF THE KISTNA DELTA, INDIA.

(With two-page plate.)

Southern India, with its dense population and limited and precarious rainfall, is largely dependent for the welfare of its people upon irrigation and the control of its great rivers. An interesting descriptive and historical account has recently appeared concerning the reclamation of the delta of the Kistna River, in India; a large area of exceedingly fertile land, which, under previous conditions of unrestrained flood, was a sparsely settled and practically waste part of the Madras Presidency. This account is compiled by Mr. George T. Walch, M. Inst. C. E., former Chief Engineer for Irrigation of the Madras District, and is published as a government document at Madras.

The Kistna River basin is of enormous extent. It practically extends across Lower India, from the Arabian Sea to the Bay of Bengal. On the west its watershed is fixed by the summit of the Western Ghats, a mountain range extending along the shores of the Arabian Sea for nearly 1,000 miles; nearly parallel to that coast and averaging less than 50 miles from the sea. From the eastern slope of this range all waters flow to the Bay of Bengal, as nowhere is this great barrier pierced by rivers. As a consequence, the Kistna River drains an area of 97,050 sq. miles; and the three other great rivers draining this part of India are: the Godavari, with 115,000 sq. miles of watershed; and the Penner and Cauvery rivers, with 20,000 and 26,266 sq. miles of watershed, respectively. These four rivers, with a few very minor small streams, thus drain a total area of 338,100 sq. miles bordering the eastern coast of the Madras Presidency.

The traditional fountain-head of the Kistna issues from a spout, fashioned into the form of a cow's head, located in the temple of Mahadeo, near Mahabaleshwar, the summer residence or sanitarium of Bombay. This source is 4,000 ft. above sea level, and is really one of many stream-heads which uniting form the great river, which empties near Masulipatam, on the Bay of Bengal. From the source of the Kistna to the sea is a distance of about 800 miles. About 60 miles from the east coast the river passes through a range of low hills, through a gap about three-quarters of a mile wide, and beyond these hills the river flows on for 40 miles, and then divides into four mouths or delta streams. It is the region seaward of this range of hills that is now controlled by the Kistna River canal system, the dam being located at the hills, as shown by Fig. 1.

This drainage basin lies within the influence of the southwest moonsoon rains, occurring between June and October. These rains bring down a quantity of water which sometimes reaches a volume of 770,000 cu. ft. per second at Bezwada, in the range of eastern hills mentioned. This is 100 times the maximum discharge of the Thames, and nearly twice as great as that of the River Nile, where it enters its delta. After October the river falls rapidly, until by January it does not reach the top of the dam, if the head-sluices are open; and during the following three months the river dwindles to a petty stream with a discharge of not over 100 cu. ft. per sec.

The Kistna Delta territory proper covers about 2,100 sq. miles, and is divided by the river into two nearly equal parts. In the eastern part is a depression, still unfilled, called Colair, or Kolern Lake, and covering an area of about 170 sq. miles. This lake now receives little silt-bearing water, and its only outlet is a deep tidal stream about 20 miles long. The natural main drainage of the Eastern Delta was by the Budameru, draining about 500 sq. miles of upland territory, and the Pulleru, which was doubtless once a spill-channel of the Kistna, and is now practically incorporated into the Masulipatam Canal, or converted into irrigation tributaries.

The Western Delta, with an area of about 950 sq. miles, was originally drained by the old river spill-channel—or the Repalle drain; by the Tungabhadra, which ran from the hills, near Sitanagaram, to Nizampatam; and the Romperu, which drained about 500 sq. miles west of a range of sand ridges and emptied into the sea near Chinna Gaujam Creek.

The control of the waters of the Kistna and its utilization for irrigation purposes were proposed as early as 1792 by a Major Beatson, in a letter to the government. Surveys of the Kistna were made in 1796, as a result of this letter; but there the matter rested until the terrible famine of 1832-33 in the Madras Presidency again directed attention to the project. Over 200,000 people died at that time from starvation, and from the fever that followed. Various engineers reported upon the control of the Kistna; but the government took time to consider it, and it was not until 1851 that the proposed work was officially sanctioned. It was commenced in 1852 under Capt., afterwards Gen., C. A. Orr, who had already constructed the anicuts at the Canvery and Godavari rivers.

The site selected for the dam, or anicut, as this type of dam is called in India, was at Bezwada, where the two gneissic hills came within 3,900 ft. of each other, at river level. The bed of the river is pure sand, to an as yet unascertained depth; its surface was constantly changing with every flood; though two deep channels marked the natural location of the scouring-sluices, which would be first built to discharge the dry-weather flow of the river during construction, and to permit the work to proceed unimpeded by water for five months in each year.

The plan of weir first adopted was one with a long sloping apron and an extended talus of rough stone; but this was modified as follows: Instead of founding the body-wall on rough stone thrown into the river, it was set upon a double row of brick foundation wells (see Fig. 2), 4½ ft. diameter inside, sunk 7 to 9 ft. into the sand and capped with a masonry platform 3 ft. thick and 12 ft. wide. The body wall built upon this was 10 ft. wide at the base and 6 ft. wide at the top; it was built of rubble masonry for a height of 11 ft., and capped with 12 ins. of cut stone. The crest of the anicut was 15 ft. above the summer level of the river.

The apron was built horizontally for 20 ft. from the rear top edge of the 6-ft.-wide body wall, and then, for 74 ft., it sloped down 1 in 12. This apron was covered with large-sized rough stone set on end; and at the rear end of the apron was a wall, 5 ft. wide, built into the mass of the stone. Beyond this 5-ft. "bind-wall" the talus was continued with a covering of large rough stone for another 100 ft. These made the total width of the anicut 205 ft.

The under, or scouring-sluices, Fig. 3, were placed at the two ends of the dam with their floors 6 ft. above "summer level." They have 15 vents, each 6 ft. wide by 10 to 15 ft. high. The shutters, or stop plank for these channels, together with their lifting gear, are shown by Fig. 4. These sluices have front and rear aprons of cut stone, and a rear apron of rough stone, 150 ft. wide and not less than 10 ft. deep.

The head-sluices, Fig. 5, have their floors 9 ft. above summer level, and the 15 vents are each 6 ft. wide and 7 to 9 ft. high. There are two locks used in connection with these head-works, both adjoining the head-sluices, for the passage of boats into the canals. The lock-chambers are 16 ft. wide and 150 ft. long, built of rubble and cut-stone masonry.

The working season at Bezwada was five months long, extending from January to May. As Captain Orr did not take charge until March, 1852, very little work was done in that year upon the anicut. But Captain Orr, in a letter to the Board, protested against the original plan of founding the body-wall on a mass of loose stone thrown into the river. His reasons have a bearing upon the "rock-fill" dam question, and were as follows: In building the Godavari anicut, where this loose stone was used to fill up hollows in the river bed, he found that it was almost impossible to keep the dam water-tight at these places. The leakage was not mere percolation, but it came in strong, continuous streams through the open spaces between the stones, as through inverted siphons. As a consequence of this experience, he proposed to fill in the hollows on the line of the apron with stone to increase the stability of the work, and then to use sand in front of this to level up the site for his wells and body-wall, and to thus guard

against the leakage referred to. But the stone filling in the rear of the wall was objected to by the Board, as a useless expense; though they approved of the sand-leveling under the body-wall as being safer.

Work in the bed of the river was commenced in December, 1852, by excavating for the foundations of the head-sluices and locks, and some masonry was laid. An unexpected flood put a stop to all work until Jan. 5, 1853; but in the ensuing season, the head and scouring-sluices and the locks were well advanced, and some of the foundation wells for the body-wall were sunk before the southwest monsoon of 1853 stopped all work. Then the Kistna came down in one of its greatest floods, and the river rose 39 ft. above datum, which was 5 ft. below the assumed summer-level. When the river fell it was found that no damage had been done to the work on the anicut. In the season of 1854, by the end of March, the front retaining wall had been built across the river to a height of 15½ ft., or 1 ft. above the floor-level of the head-sluices. This wall was backed throughout the greater part of its length by rough stone. On Aug. 9, 1855, the anicut was reported completed; the front retaining wall was 20 ft. high above the deep bed of the river, and this was backed with blocks of rough stone aggregating half a million tons in weight, with some single blocks weighing 5 to 6 tons. Up to that time two 30-ft. floods had passed over the work without damage.

The entire cost of the anicut and its head-works, to July 31, 1855, was 772,186 rupees; or, taking the rupee at its par value, $370,649.

In 1894 the crest of this anicut was raised 3 ft. by building a continuous wall of masonry upon it; but as the apron behind it was not raised at the same time this wall was carried away in the floods of the same year. In 1897, automatic shutters, or flash boards, Fig. 6, were substituted for

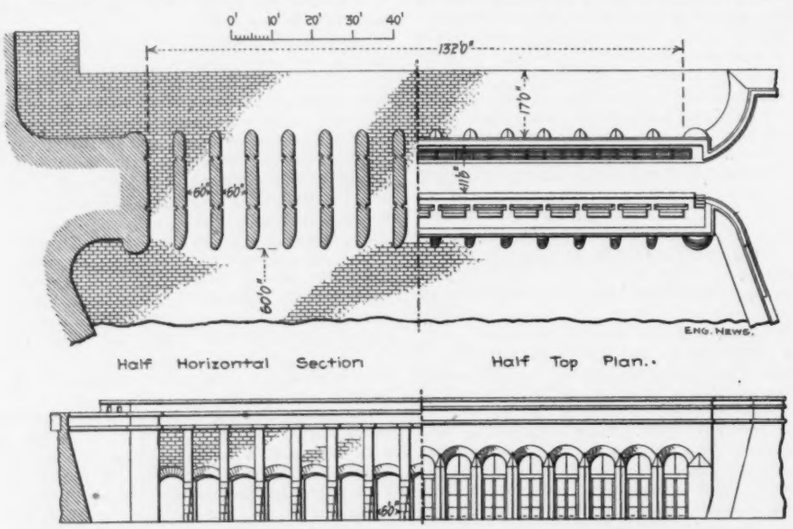


FIG. 5. PLAN AND ELEVATIONS OF HEAD SLUICE, MAIN CANAL OF KISTNA DELTA.

the solid additional wall, and these seemed to work successfully.

The building of the anicut at Bezwada was only the initial step in reclaiming the delta lands of the Kistna, for all of the territory in question had to be intersected by main and subsidiary canals for irrigation purposes and control of water. This development work is not described in detail in the report; but some notes of the chief canals are given as follows: The so-called Main Canal is only 53 chains long, counting from the Bezwada head-sluices; but it then branches into the Ellore, Ryves and Masulipatam canals. The first of these —the Ellore Canal—has a fall of over 1 to 2 ins. per mile for the 40 miles of its course to the town of Ellore, where it connects with the Godavari Canal, which completes the 87 miles of inland navigation connecting the two great rivers. This canal starts with a bottom width of 60 ft., and ends with 36 ft.; and the depth decreases from 8 ft. to 5 ft. 9 ins. As the Ellore Canal lies above the alluvial tract of the delta, there is little irrigation possible on its left side; but towards the sea it irrigates 48,000 acres.

The Ryves Canal supplies upwards of 45,000 acres; for 12 miles it has a bottom width of 90 ft., a depth of 7 ft., and a uniform fall of 7 ins. per mile. In its additional length of 9 miles it is cut up into numerous branches, and then joins the Pulleru. The Masulipatam Canal is nearly 50 miles long, and is divided into five reaches by locks. The bottom width is 80 ft., and the depth 8 ft.; but when it reaches the Bank Canal the width is reduced to 67 ft., and the depth to 7 ft. 6 ins.; beyond Kankipad lock the width is again reduced to 25 ft. and the depth to 5 ft. Besides these canals there are other large distributors, such as the Poiraz, Bantumilli, etc. In 1897-98 these canals irrigated 301,072 acres in the Eastern Delta.

The Main Canal of the Western Delta runs due south for 13 miles, with a bottom width of 230 ft., for 7¾ miles, and then 170 ft. It carries at times near 4,000 cu. ft. per sec. The direct irrigation from this canal is only 10,000 acres. But at the 7¾-mile point the Bank Canal leaves the Main Canal—with a lock. This canal is 46 miles long, and is divided into four reaches by locks. It irrigates 56,234 acres. The Commamur Canal leaves the Main Canal 12 miles from its beginning and runs southwest for 58¼ miles. It is divided into five reaches by locks, and irrigates 91,162 acres, chiefly on its left side. The Nizampatam Canal leaves the Main Canal at the same point as the Commamur Canal, and runs nearly due south for 28 miles. It irrigates 62,447 acres. These four canals thus irrigated, in 1897-98, 218,850 acres of the Western Delta.

In addition to these irrigation canals there will be found on the map, Fig. 1, a number of mere drainage canals, such as the Repalle, Bhattiprole and Peddapalli Drains. The river itself is leveed for 52½ miles through the delta.

It might be mentioned that, in designing these channels, up to about 1879, Du Buat's formula was employed; but since that time Bazin's formula alone is used. This is:

$$V = c \cdot \sqrt{r \cdot s},$$

Where V = velocity in feet per second; r = hydraulic radius, or hydraulic mean depth, in feet; s = fall in unity, of surface, and c = a variable coefficient, which in earthen channels is arrived at from the formula

$$C = \frac{1}{\sqrt{0.00008534\left(\frac{r + 4.1}{r}\right)}}$$

The side slopes generally adopted for earthwork in the delta are 1 on 1½.

Brickwork is little used except in arches. Nearly all work is in concrete and rubble masonry with ashlar facings, quoins and coping for the more important works. This concrete is generally made as follows: 3 parts of stone broken to 2-in. gage, and 1 part mortar, laid and rammed in 6-in. layers. Wherever the foundations are wet, and often in the superstructure, this mortar is made of 1 part slaked lime, 2 parts of river sand and ½ to 1 part of finely-ground brick dust, known in India as "surki." The addition of the surki makes the mortar eminently hydraulic.

The locks are of two classes; the first having a chamber 150 × 20 ft., and the second a chamber 105 × 15 ft. The lock-weirs and surplus-weirs are given a length capable of discharging the maximum required with a depth of 2½ to 3 ft. on the crest; the latter being provided with wooden shutters commanding that height, handled by screw-gearing; these shutters are usually 9 ft. long. The weir adopted has a vertical overfall, on a water-cushion underlaid by concrete. The ogee form of weir at first used, has given endless trouble; due to the velocity imparted by this form doing as much damage as the shock, and also creating a standing wave below the fall which washed the banks. All of the modern irrigation sluices are fitted with shutters worked by screw gearing; and as a rule, the sluices are widened out behind the shutters, to reduce the velocity of discharge and thus do less damage to the banks and bed.

Irrigation is the primary object of the Kistna works, and various reservoirs have been planned above the delta itself for the storage of flood water; but none seem to have been built as yet. In 1874-76, the "duty" of the Kistna water was assumed at 1 cu. ft. per sec. for every 74 acres; while 81 acres was adopted, in 1882, for the Godavari Delta. In 1894, Prof. Chatterton, of the Civil Engineering College of Madras, concluded that the duty of the Kistna water may be taken at 90 acres per cu. ft. per sec.; and at times of short supply, 100 acres might be assumed, "if care be taken to prevent the waste of water." He thought it was possible to obtain a minimum supply of 8,000 cu. ft. per sec. up to the end of November in each year; and his figures finally led to the conclusion that the probable ultimate area to be irrigated in the Kistna Delta would amount to 700,000 acres; as contrasted with the 519,922 acres irrigated in 1898. Rice is the chief crop now grown in the delta; and nine-tenths of the lands in India taking anicut water grow this crop, as it requires continuous watering for from 3½ to 6 months, according to the kind of rice grown. The better kinds require the longer time.

The water-rate charged is as follows, for both the Kistna and the Godavari Deltas: For a single wet crop, 5 rupees ($2.40 at par of rupee) per acre. For a second wet crop on irrigated land, 5 rupees—provided, that the cultivator may compound for irrigating two crops for a term of years, not less than 5, for 8 rupees 2 annas per acre. For a second dry crop, 2 rupees 2 annas per acre, if the crop is watered only occasionally; and 3 rupees 12 annas, if the irrigation is systematically done at regular intervals. He may compound for this as for a wet crop. These rules apply to various other Indian crops and methods of irrigation.

The aggregate length of irrigation distributaries in the Kistna Delta system is about 1,600 miles. The total average rainfall is 36.64 ins. per year, divided as follows: January to March, 0.91-in.; April and May, 1.98 ins.; June to September, 21.72 ins.; October to December, 12.03 ins. In this system about 300 miles of canals are navigable, and form part of an inland system of navigation upwards of 1,000 miles in length, including the 500 miles of Godavari canals, and the 196 miles of Buckingham canal running to Madras and 65 miles beyond it.

The total amount expended upon this Delta system, from 1852 to the end of the fiscal year, 1897-98, was about $6,595,833; and up to the same date there was a clear surplus of receipts over all expenditures and charges of $9,347,254, or nearly half as much again as the whole capital expended. In 25 years the population of this district has increased from 1,296,652 to 1,855,582, scattered over 8,498 sq. miles.

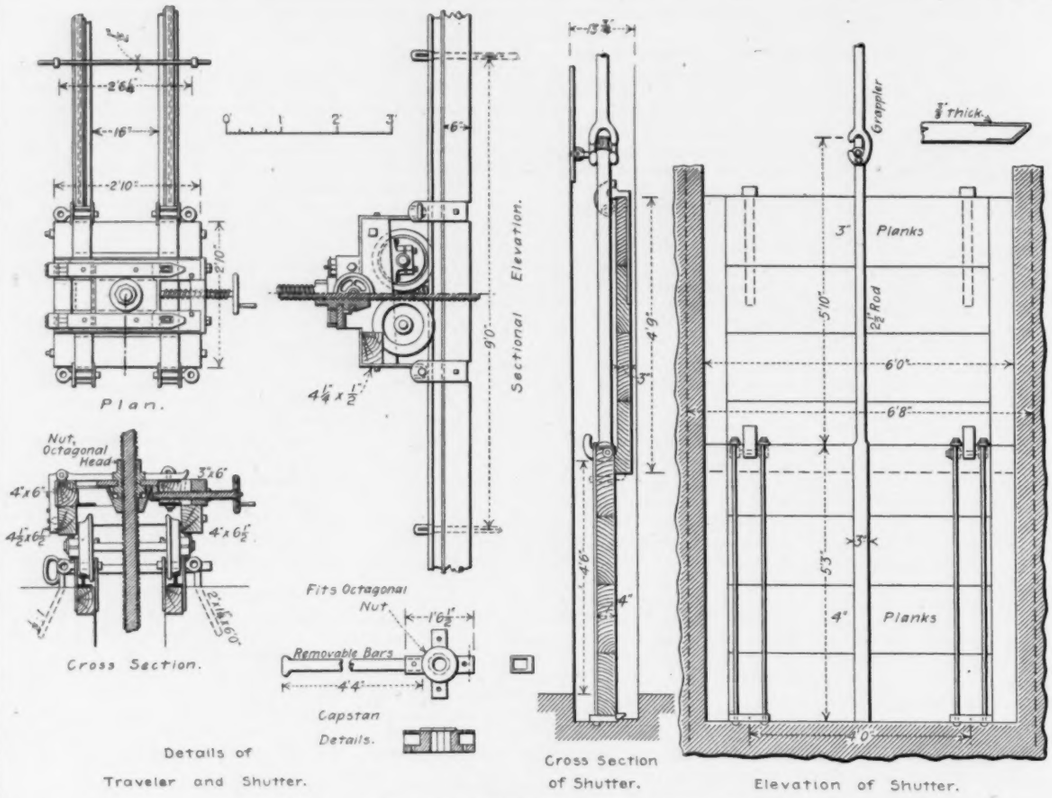


FIG. 4. DETAILS OF SHUTTERS WITH LIFTING GEAR FOR UNDER SLUICES.

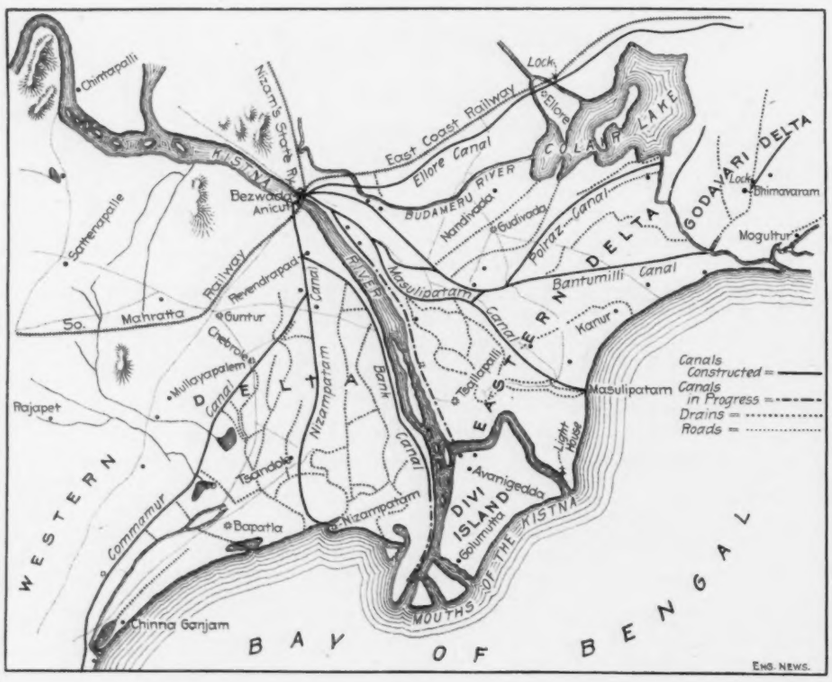


FIG. 1. MAP OF THE KISTNA DELTA SYSTEM.

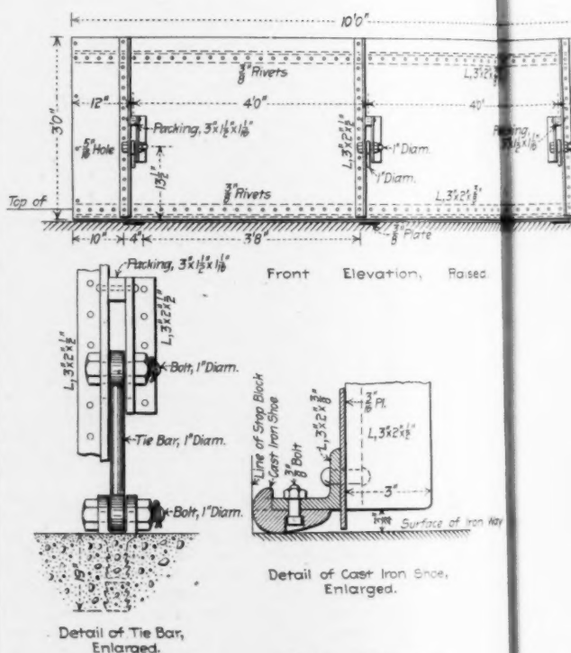


FIG. 6. DETAILS OF AUTOMATIC SHUTTERS FOR THE ANICUT.

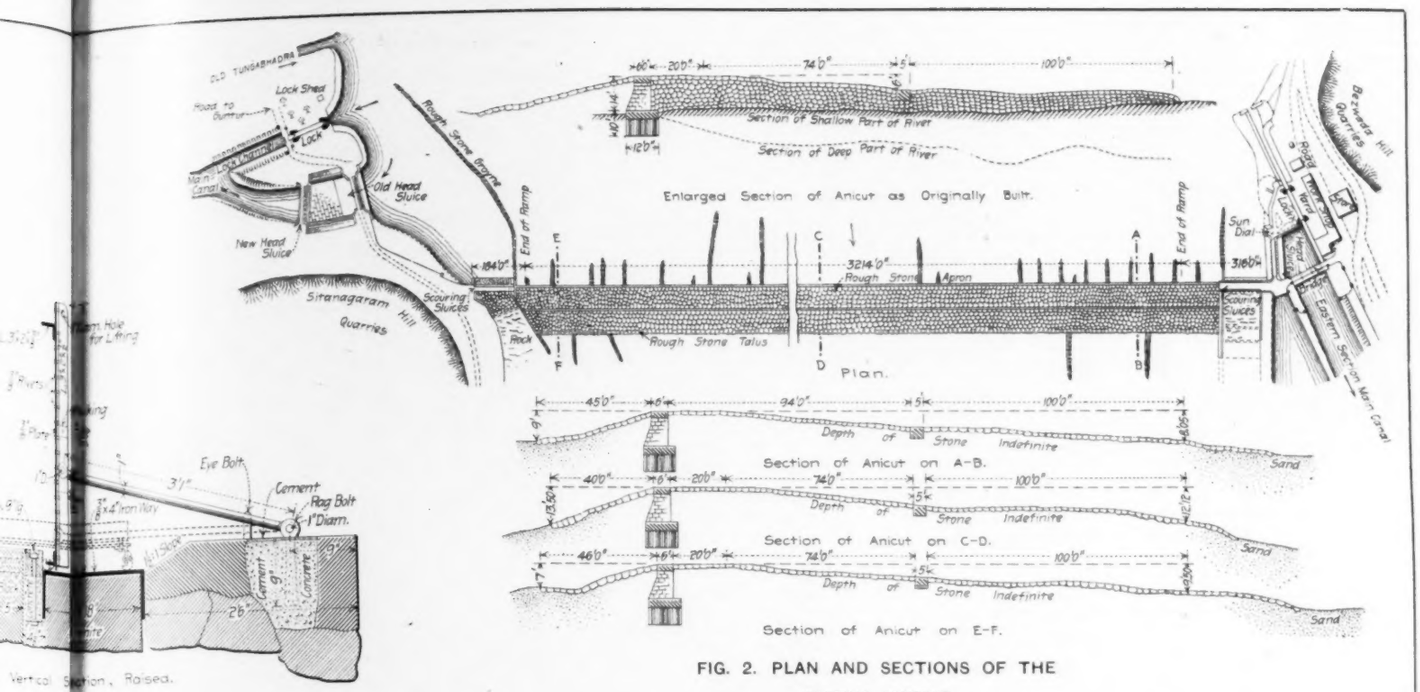
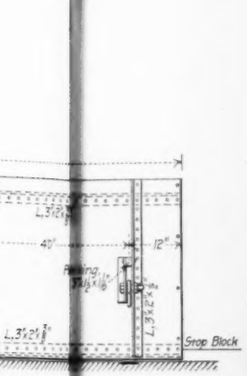


FIG. 2. PLAN AND SECTIONS OF THE KISTNA ANICUT.



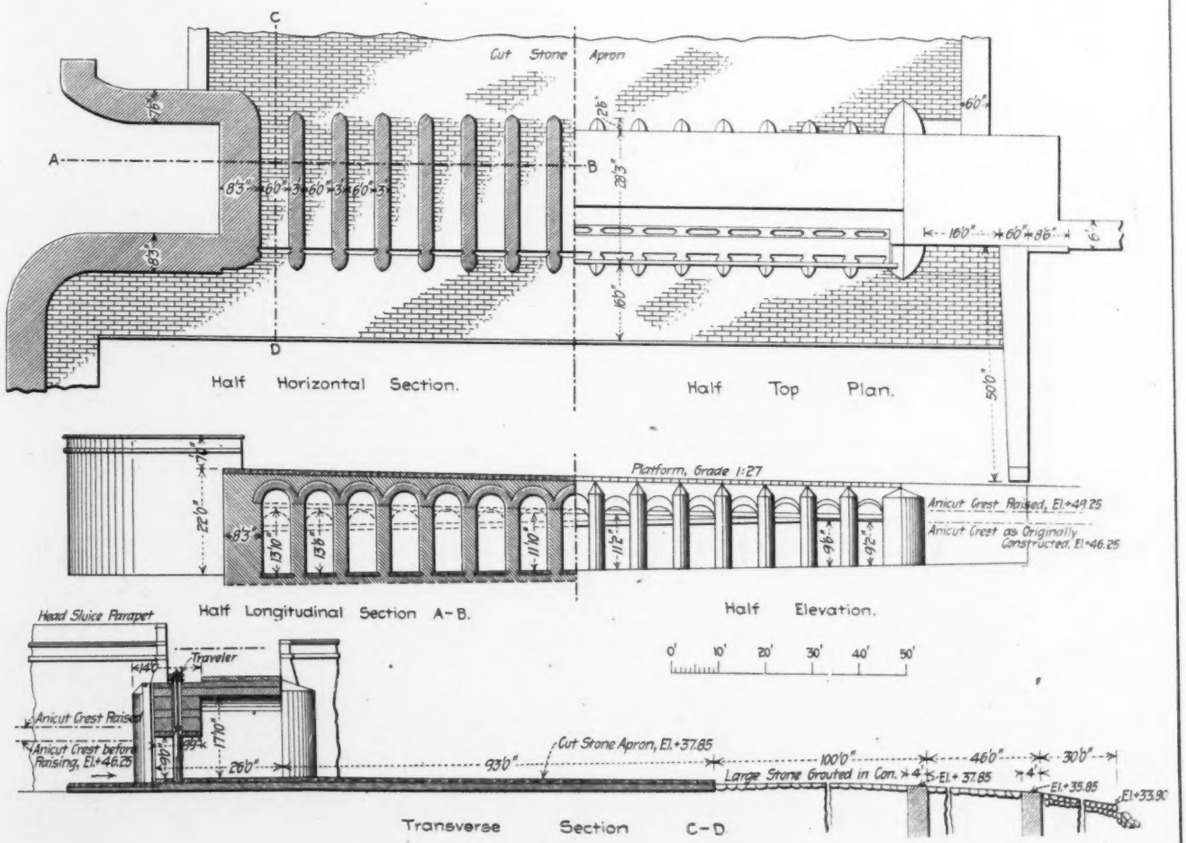


FIG. 3. PLAN AND SECTIONS OF UNDER SLUICES.

ID IRRIGATION OF THE KISTNA DELTA,
AS PRESIDENCY, INDIA.